CANMET

Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

MINERAL SCIENCES LABORATORIES

ANNUAL REPORT 1985/1986

APRIL 1986

MINERAL SCIENCES LABORATORIES
DIVISION REPORT MSL 86-81(TR)

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MINERAL SCIENCES LABORATORIES

ANNUAL REPORT 1985/86

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY
ENERGY, MINES AND RESOURCES CANADA

DIVISION REPORT MSL 86-81 (TR)

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FOREWORD

The annual report for this Fiscal Year 1985-86 is taking on a new look, by the addition of highlights which should permit the reader to obtain a flavour of the Mineral Sciences Laboratories (MSL) work before delving into the details.

This report summarizes the activities of MSL for the year and is intended as a review for CANMET management and staff and as a working document for preparing other branch publications.

For operational purposes the division is made up of three laboratories, the Chemical Laboratory (CL), the Extractive Metallurgy Laboratory (EML), the Mineral Processing Laboratory (MPL), one separate program called the National Uranium Tailings Program (NUTP) and Administration which includes overhead costs for the laboratories.

The resources assigned to the laboratories and the program in 1985-86 were as follows:

Laboratory	Person Year	Operating $(000)	Salaries $(000)	Capital $(000)	Contracts $(000)
141-Administration	20	382	759	5	-
142-CL	44	167	1,738	281	43
143-MPL	70	447	2,949	416	1,917
144-EML	56	328	2,201	360	1,272
187-NUTP	6	49	327	48	2,062
	196	1373	7,974	1,110	5,294

L.L. Sirois
Director

AVANT-PROPOS

Le rapport annuel de l'année fiancière 1985-1986 se présente sous une forme renouvellée en ce qu'il souligne des faits saillants qui devraient donner aux lecteurs un aperçu des travaux des Laboratoires des sciences minérales (LSM) avant d'en connaître le détail.

Le rapport résume les activités des LSM pour l'année en cours et se veut un examen critique pour le bénéfice des directeurs et du personnel du CANMET ainsi qu'un document de travail qu'il sera possible de consulter lors de la préparation d'autres publications de la Direction.

À des fins d'exploitation, la Division comprend trois laboratoires dont le Laboratoire de chimie (LC), le Laboratoire de métallurgie extractive (LME), le Laboratoire de traitement des minéraux (LTM), un programme particulier intitulé Programme national de recherche sur les résidus d'uranium (PNRRU) et le programme de l'Administration qui inclus les frais généraux des laboratoires.

Les ressources financières allouées aux laboratoires se répartissent ainsi:

Laboratoire	Années-personne	Crédits d'exploitation (000)$	Salaires (000)$	Crédits d'immobilisation (000)$	Contrats (000)$
141-Administration	20	382	759	5	-
142-LC	44	167	1 738	281	43
143-LMP	70	447	2 949	416	1 917
144-LME	56	328	2 201	360	1 272
187-PNRRU	6	49	327	48	2 062
	196	1 373	7 974	1 110	5 294

L.L. Sirois
Directeur

HIGHLIGHTS

CHEMICAL LABORATORY

The Chemical Laboratory carries out research, development and analytical support services for CANMET's Mineral and Earth Sciences Program; provides a consulting service and technical assistance in the field of analytical chemistry to other federal and provincial government departments and agencies, and to industrial organizations and universities; prepares, certifies and distributes Reference Materials to improve quality control in the Canadian Minerals processing industry; participates in committee work for national and international organizations; and provides the sole Canadian analytical umpire service for uranium determination in uranium concentrates to resolve disputes between supplier and refiner.

During this review period significant progress was made in analytical research and development using liquid and gas chromatography. Analytical procedures using liquid chromatography were developed for determining rare earth elements and yytrium in uranium ore processing products. Contributions were made to the liquid chromatographic methodology for determining the following anionic species: organic acids in lysimetric leaching solutions from Elliot Lake uranium tailings; sulphoxy anions in cyanide barren effluents and products from coal desulphurization processes; and cyanate and thiocyanate in cyanide barren effluents from water pollution control investigations. Gas chromatographic procedures were developed for the analysis of tributylphosphate and kerosene in effluents from solvent extraction processes.

Experimental work has shown that many elements found in solution samples from hydrometallurgical process solutions can be determined rapidly and directly, often without prior separation, using atomic-absorption spectrometry (AAS), inductively-coupled plasma-atomic emission spectrometry (ICPAES) and X-ray fluoresence (XRF). Also, it was found that trace and moderate amounts of many elements in ferrous and nonferrous alloys, environmental materials and products from hydrometallurgical processes can now be determined routinely using ICPAES. Graphite furnace AAS, which is a more sensitive technique for trace elements, and hydride-generation - AAS are being investigated for determining small amounts of metals in process materials.

Methods have been developed for determining small quantities of antimony, bismuth, silver, copper, cadmium and indium in ores and related materials using simultaneous group extraction of the iodides before final AAS determination of the element. These procedures are of particular use for analysing candidate Certified Reference Materials for CANMET's CCRMP project and for zinc processing products resulting from CANMET's silver recovery project.

The Chemical Laboratory makes a core contribution to CANMET's Standard and Specifications Sub-activity through the Reference Materials (CCRMP) project which provides Canadian industry with documented reference materials, especially those having compositions that are characteristic of Canadian mining and mineralogical sites. Revenue from the sale of CCRMP products increased by approximately 10% last year to exceed the $100,000 level. A uranium and a gold ore were certified and offered for sale; interlaboratory programs for two other gold ores have been completed; and certification of a suite of seven zinc - aluminium alloys is nearing completion. The preparation facilities of the CCRMP were improved by the addition of a high-capacity dust collection system. This preparation facility is increasingly being recognized as a resource centre for reference sample preparation by industry and other agencies, preparative services being provided for three such projects in the past year.

Participation continued in national and international committee work, in particular for the International Organization for Standardization (ISO). Some examples were REMCO, the council committee on reference materials; TC 102 for iron ore standards; and TC 183 for standard methods of chemical analysis of copper, lead and zinc ores and concentrates.

A manual of CANMET methods for the determination of gold, silver, platinum and palladium in ores, concentrates and related materials has been completed for general distribution.

The Chemical Laboratory participated in MSL's cost recovery work, in particular for contracts requiring gold determination in Royal Canadian Mint Sweeps and the determination of four radioisotopes using high-resolution gamma-ray spectrometry.

A new vibrating magnetometer has made possible the routine determination of magnetic susceptibility and hysteresis loop measurements which in conjunction with Mössbauer spectroscopy data has permitted the characterization of various products from some of CANMET's processing operations.

EXTRACTIVE METALLURGY LABORATORY

The Extractive Metallurgy Laboratory undertakes activities over a wide research range from improved understanding of physical chemical phenomena as a contribution to the science knowledge base to resolving in-plant operating problems as a direct service to industry. The evolution of in-house research is influenced by perceived gaps in information and technology, advice from industry and changing policy directions.

Transfer of technology to industry is considered to be the ultimate goal of effective research. Such items have included:

a) Evaluation of process options and scientific support for field testing of thiosalt destruction technology in New Brunswick.

b) Development of process technology for cyanide recovery from gold process effluents in Ontario.

c) Establishment of analytical techniques for trivalent and pentavalent arsenic in electrolytic process solutions.

d) Characterization and recommended process modification to resolve a severe emulsion problem in a solvent extraction circuit for a Canadian Company.

e) Identification and resolution of a biofouling problem in an iron ore plant.

f) Scientific and technical support for an in-place biological leaching ore leaching project in Ontario and Manitoba.

g) Establishment and confirmation of an evaluation technique for limestones for sulphur capture in fluidized-bed combustion.

h) Development of an ohmic contact for GaAs circuits.

Significant activities in the laboratory in several fields are aimed at becoming the technology of the future. Such areas include photoelectrochemistry, the harnessing of solar energy to effect specific reactions by accelerated oxidation or by photocatalysis utilizing inexpensive materials such as hematite.

In the area of solution chemistry, work on iron precipitates has aided industry in understanding losses of valuable metals such as silver and is leading to new approaches in iron control. Speciation of metals in solution is increasing the understanding of hydrometallurgical phenomena. Electrochemical research has been instrumental in improving efficiencies in existing plants and guiding new developments. A cooperative project with Canadian copper refiners has been established to improve productivity and reduce cost.

A major activity has been in perfecting a ferric chloride leaching process to effect high recoveries of zinc, lead, copper and silver from complex sulphide ores. The chemistry of the circuit is well understood and engineering factors are being more precisely defined.

Research on improving uranium extraction technology has reached a mature state of development. The major outputs have been spin-offs in several areas, particularly in establishing a strong basis for resolving problems related to recovery of byproduct metals in the uranium, aluminum and precious metals industries. By-products such as gallium, rare earths, nickel, cobalt, platinum metals and tantalum have been the subject of research.

A 150-KVA extended arc (plasma) furnace has been installed as a research tool in developing a better understanding of the metallurgical potential of plasma. A number of studies have been supported to help focus work on those areas most opportune for Canada.

Work on the physical chemistry of slags and pyrometallurgical emissions is improving understanding in these fields. This has become the basis for the development of an on-stream arsenic analysis probe for gaseous emissions.

Biotechnology has become an area of increasing interest. Research in-house and under contract is evaluating the potential for application of bioleaching and biosorption of metals. Under contract to CANMET, Noranda Research identified and quantified the criteria for mine selection for in-place bioleaching. A network called BIOMINET has been instrumental in significantly improving communications between researchers and industry in this new field of biotechnology.

The interrelationship between physical, chemical and biological factors in tailings are being characterized in an effort to better predict and control long-term behaviour. The effects of various strategies such as wetlands cover and deep lake discharge are being evaluated.

Special expertise is also used to serve specific requirements. Significant contributions are made to Canadian and International standards for ores and concentrates through statistical analysis expertise. New techniques for mine dust analysis are being evaluated. Thermal analysis of a wide variety of materials aids clients in more fully understanding reactions such as calcination, pyrolysis and sorption.

In-house work has been extended by contracts to the private sector. Significant progress has been made in photoelectrolysis evaluation of plasma for metallurgical applications, lead electrolysis, gold processing and environmental controls via such contracts.

Such is the scope of activities of the Extractive Metallurgy Laboratory. Further detail on this work is contained in the body of the annual report.

MINERAL PROCESSING LABORATORY

The Mineral Processing Laboratory carries out in-house investigations and contract studies in support of the needs of the Canadian minerals industry. The program is developed in close consulation with the industry and with the provinces (through Mineral Development Agreements) and is carried out in cooperation with industrial R&D performers, private research companies, provincial research organizations and the academic community. Major projects are underway in the processing of metallic ores, coal, and industrial minerals, in the development and testing of improved construction materials, especially concretes, and in the preparation and treatment of ceramic products, both traditional and advanced. These activities are supported by a range of mineralogical investigations, particularly aimed at process design.

- In construction materials, the program to develop supplementary cementing materials (alternatives to cement) from a variety of otherwise waste products (fly ash, silica fume, ferrous and non-ferrous slags) had a major achievement this year. Following in-house and contract development work by MPL, Reiss Lime Company of Canada Limited has begun the construction of two facilities at Sault Ste. Marie and at Spragge, near Blind River, Ontario to produce 200,000 tonnes of slag cement from Algoma Steel Corporation's blast furnace slag. The $13M facilities will provide 25 direct jobs and will substantially reduce the cost of concrete in the area, where the major demand is for mine backfill.

- In the processing of metallic ores, coal, and industrial minerals, a computer simulation package called SPOC (Simulated Processing of Ore and Coal) has been made widely available. SPOC is one element of a package, comprising on-stream chemical and size analyses, monitoring of mass flows and computerized process control, that is beginning to show massive savings. One Canadian company reports savings of 30% in grinding costs due to proper grinding simulation and control. The simulation of a variety of grinding, sizing and separation devices has been completed. The models are now accessible through CANMET, either using EMR's main frame computer or purchased outright for use with IBM compatible equipment. A complete set of manuals is also available.

- In this same area, through the work of dedicated individuals, CANMET's competence in the treatment of industrial minerals has been largely restored to the level enjoyed in the 50's and 60's. Equipment has been restored and replaced, knowledgable staff have been acquired and trained and industry is again developing a reliance on our capabilities in this area.

- In ceramics, major progress has been made in the development of ceramic solid electrolytes for applications in H_2/air fuel cells, hydrogen sensors and pumps, electrolysers and tritium recovery devices (e.g., for decontamination of nuclear reactor spills). Work has centred on the development of a hydronium-ion conducting form of β-alumina for the solid electrolyte, prepared by ion exchange of other cationic forms. Unfortunately, this material is unstable at high temperature, which precludes conventional sintering. However, during this review period, a technique has been developed for low temperature bonding of hydronium β-alumina with a phosphate bond that is itself ion-conducting. The product is a dense, strong ceramic membrane suitable for use in a variety of devices (as above). A patent has been applied for.

- In mineralogy, MPL has completed major upgrades of much of its mineral characterization equipment, making it the best equipped lab of its kind in Canada and one of the best in the world. The flagship is the automated image analysis system which uses a fully integrated image analyser and a scanning electron microscope (SEM). This instrument is used for particle measurement and liberation analysis of minerals in ores, feeds and process products. Following a demonstration of its application to members of the mineral processing community, the industry has placed a heavy demand on its use. In addition to this equipment, MPL has an automated electron microprobe/SEM for chemical analysis of minerals and other materials and a four-circle, single crystal X-ray diffractometer equipped with liquid nitrogen specimen cooling, which is used for analysis of the crystal structure of minerals and compounds formed during beneficiation/extraction of minerals. Also, there is a computer controlled 12 kW, rotating anode, X-ray generator equipped with an

automated goniometer, a micro-diffractometer for in-situ determinations and a capability of automatic search/match of the characteristic diffraction lines from the sample. This equipment, complemented by a cadre of expert staff and other instrumentation, will play a major role in the development of new mineral deposits and in the improvement of existing mineral processing circuits.

THE NATIONAL URANIUM TAILINGS PROGRAM

In 1981, after a year-long study, the National Technical Planning Group on uranium tailings research, under the direction of Philip Lapp, concluded that there was not enough scientific data to predict confidently the long-term effects of uranium tailings on the environment (1). This group of experts, appointed by the Department of Energy, Mines and Resources Canada, recommended that a research program be conducted to fill the knowledge gap. The Government of Canada responded to this recommendation by announcing in 1982 the formation of the National Uranium Tailings Program (NUTP). This is a five-year research program with approximately $8.5 million in funds that is studying the ways to predict the effects on the environment of uranium mill tailings over the long-term (2).

The main objective of the Program is to provide a scientifically credible information base which will assist government regulatory agencies and mining industry to establish long-term management strategies for the protection of the public and the environment. The Program is reviewed and receives advice from a Technical Advisory Committee which includes representatives from both Federal and Provincial governments and members of Canada's active mining industry. This group meets on a regular basis and reviews the work done to date and makes recommendations for future work. In addition to providing theoretical and technical assistance, the mining company representatives have also provided practical help which has allowed several projects to proceed smoothly. The TAC has also been a forum for raising issues of joint concern between the industry and various governments involved. Once these issues were identified, the NUTP were able to initiate projects that developed sufficient data to make rational decisions.

The needs of three constituencies, i.e. the regulatory authorities, the mining industry and the public are being kept in mind as the work proceeds. It is these three groups who will judge the acceptability of the risks involved. The NUTP will provide a solid scientific background against which these judgements can be made.

A secondary objective is to develop the scientific skills required to assess long-term effects of uranium mill tailings in Canada. In particular, it is hoped to encourage the development of environmental research expertise within the private sector. To this end the bulk of the research programs have been awarded by competitive bid to privately owned Canadian consulting and research companies.

In 1986, the National Uranium Tailings Program was approaching the end of its five-year mandate. Priority was given to use the remaining resources to develop a better understanding of the fundamental science associated with long-term consequences of uranium tailings. The currently available resources will allow completion of the development stage of the Program and will result in a functional model to predict the long-term consequences of uranium tailings on mankind and the environment.

The staff consisted of three Project Managers, one Contract Officer, one Office Manager, one Secretary, and one short-term Research Assistant. During the 1985/86 fiscal year, 17 new contracts were issued, which when added to the existing 22 ongoing contracts made a total of 39 for the year.

The 1985/86 budget was allocated as follows:

	$M
Salaries and benefits	0.28
Capital	0.05
Operating	0.07
Contracts	2.32
Total	2.72

and resulted in

- 4 technical presentations
  (1 published paper)
- 33 Technical Contract reports
- 1 Probabilistic Predictive Computer Model
  (UTAP, Phase II)
- 4 NUTP Reports

More details on the status of the Program to March 31, 1985 can be found in the Interim Report (NUTP 85-6) issued in April of 1985. It is intended to issue a second interim report early in the 1986/87 fiscal year, which will be, in effect, an executive summary of the work to date.

MINERAL DEVELOPMENT AGREEMENTS

Under the "umbrella" of the Economic and Regional Development Agreements, the federal government and the provinces have established a number of federal/provincial Mineral Development Agreements (MDA's). The objective of these agreements is to strengthen and diversify the mineral industry in a province to enable minerals to make a maximum contribution to the provincial economy and to reduce the impact of economic down-turns. Projects undertaken identify and evaluate mineral deposits and develop appropriate mineral processing and extraction methods in order to promote and accelerate development opportunities.

The Mineral Sciences Laboratories of CANMET has major responsibilities for the Mineral Technology component of those MDA's which involve joint federal/provincial program delivery. (Certain MDA's are solely provincially delivered.) Thus MSL is involved in MDA's with Newfoundland, Nova Scotia, New Brunswick, Manitoba and Saskatchewan. The research work is carried out by contractors selected from industry or from private or provincial research organizations. MSL's role is, in consultation with the provinces, to prepare work programs, provide expert advice and guidance and act as Scientific Authorities on contracts. With perhaps 20 MDA contracts underway and 85/86 expenditure nearing $3M, this is a major element of MSL's program and places a large demand on MSL staff.

During the 85/86 period, the effort in the Newfoundland MDA was directed towards improved iron ore processing and the assessment of base metal sulphide deposits. In Nova Scotia, work was focussed on identifying and developing new sources of industrial minerals and construction materials while in New Brunswick, it was on construction materials and developing extractive processes for sulphide minerals. In Manitoba, most work was devoted to industrial minerals and to the reduction of sulphur emissions in the extraction of sulphide ores, and in Saskatchewan, to the dry processing of potash.

In subsequent sections of this document, MDA contracts are described as part of the Project under which they fall (e.g., the Newfoundland MDA contracts on iron ore are described under the MSL Project Iron Ore Processing). MDA contracts are designated as such by the letters MDA written after the Contract Requisition Number.

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PART A. RESEARCH AND DEVELOPMENT

MINERAL AND ENERGY TECHNOLOGY ACTIVITY

MINING SUB-ACTIVITY

Rock Mechanics

- **Project 14.25.05:** Underground Nuclear Waste Repository
  Project leader : V.V. Mirkovich

Objective:

To characterize petrographically rocks occurring in sites being examined for possible disposal of nuclear wastes, and determine their thermophysical properties from representative specimens.

(a) Samples of thirty rocks from the Underground Research Laboratory at Pinawa, Manitoba and from drill cores have been studied and samples prepared for thermal testing. Petrographic reports are being completed, and measurements of the thermal expansion, conductivity and diffusivity of the rocks will now be made. The thermal diffusivity apparatus is finally operational, after a lengthy period of malfunction.

(b) Report:

- MRP/MSL 85-15 (J)

Mine Environment

- **Project 14.39.01:** Ventilation and Respirable Dust
  Project leader : J. Bigu (MRL)

Objective:

To characterize dust in underground and surface mines, assess sources and control measures, and develop methods of measurement.

(a) Infrared determination of quartz in mine dust

The presence in mine dust of other minerals can interfere with the determination of quartz by infrared (IR) absorption. Absorption bands due to these minerals can distort the 800 - 700 cm^{-1} quartz doublet if they occur in this wave number range or can cause sloping baselines when the doublet is superimposed on a large outer wing of a band, making baseline determination difficult.

Samples of respirable dust taken at typical sampling areas were obtained from ten mining companies. Of thirty samples, only eight had respirable dust weights of over 500 mg. Four samples had a quartz content equal to or greater than the safety threshold limit value of 100 µg/cubic metre of air. Sixteen samples had a quartz content above the detection limit. The peak area of the quartz doublet was calculated without interference from the background matrix for five of these samples. Baseline irregularities due to sample and reference filters became very significant for low quartz levels.

There was considerable variation in the composition of the dust obtained from different mines. The major interferences with the IR method were caused by the presence of clays and carbonate minerals. The computer program was used to calculate doublet peak area, 800 cm^{-1} peak height, and 780 cm^{-1} peak height. The 800 cm^{-1} peak height calculation was used for eleven samples where the peak area was affected to a greater extent by matrix interference. The program has an option which allows choice of doublet minima for the baseline determination. This option was used in the examination of four of the samples to reduce some of the matrix interference. A more rigorous investigation of the particular interference problems associated with individual mines would require the examination of filters with heavier dust deposits. Spectral subtraction of background interferences, a capability the laboratory does not at present possess, could possibly be used in some cases where representative matrix dust could be obtained.

In order to prepare samples of quartz on filter membranes by air deposition in the laboratory, work is proceeding on the construction of a small dust chamber. The sampling system used at present consists of a 25 mm diameter Millipore filter cassette with DM 800 filter membrane, a 10 mm nylon cyclone and a Gilian HFS pump. The dust cloud is created from ground silica sand.

(b) Dust suppression

The dust originating from sulphide minerals exhibits an inherent hydrophobicity that makes water spreading on the surface of the particles more difficult, creating problems in dust suppression. The possibility of using surfactants as wetting assisting agents for the suppression of sulphide ore dust has been investigated in the laboratory. A large number of surfactants, obtained from the industry, were examined to determine their ability to perform as wetting agents for the sulphide dust. The wetting power was evaluated based on a laboratory procedure, measuring the sinkage rate of the dust spread on the surface of various surfactant solutions. The most suitable wetting agents were selected and further investigations were carried out to determine the effect of the dust-suppression agents on

the flotation process. The results of these tests indicated that the flotation selectivity, particularly in the case of polysulphide ores was adversely affected by the presence of the wetting agents used in this study.

The investigation continues to identify and select other wetting agents more suitable for this application. Also testwork is underway to study the possibility of eliminating the detrimental effect of the surfactants in the sulphide ore flotation.

New surfactants supplied by Dow Corning, G.A.F. and Alchem proved to be better dust suppressors than the ones experimented with previously, but they had the same detrimental effect on the flotation results. The adjustment of the flotation reagents to eliminate the adverse effects of wetting agents did not succeed in improving the flotation selectivity and results. The manufacturers of the selected surfactants were contacted to investigate possible conditions for surfactants destruction after their use as dust suppressors. No positive response has been received yet on this route of investigation. The elimination of the surfactants by adsorption on activated carbon was tried under various conditions: carbon added in the mill and floated separately or together with the copper, carbon added after grinding in a conditioning stage and removed prior to minerals flotation. The removal of the surfactants when carbon was added to the slurry after grinding proved to be more efficient. Also this method offered the advantage to recuperate and re-use the carbon.

Tests to eliminate the adverse effect of the surfactants on Opemiska ore flotation have been completed. Under selected conditions (carbon addition and conditioning time) it was possible to reproduce the standard flotation results even when an exaggerated large amount of surfactant was present in the ore. The work to eliminate the detrimental effect of the surfactants on Kidd Creek flotation is in progress.

Contacts have been initiated with the potash industry to identify dust problems in their underground mines.

COAL MINING AND PREPARATION SUB-ACTIVITY

Coal Desulphurization

- **Project 20.79.01:** High Sulphur Coals
  Project leader : L.L. Sirois

Objective:

To contribute to the technology of economically upgrading high sulphur coals to meet more stringent specifications for thermal and metallurgical coals and future requirements for coal combustion, conversion and environmental considerations.

Coal preparation to remove ash, sulphur and other contaminants will generally be necessary for coal destined for liquefaction and gasification. Preparation will also be increasingly important in thermal coal production, especially to reduce sulphur in eastern coals, where atmospheric environmental regulations are becoming more stringent. Metallurgical coal must in the future be produced from poorer quality raw coal and this will require improved fine and oxidized coal treatment. Removal of unwanted components also contributes to decreased transportation costs.

(a) Magnetic treatment of Canadian coals

The dry magnetic beneficiation of Canadian coals was completed on Prince and Lingan (DEVCO) and Kipp (Petro Canada) coals using both the high-gradient conventional and superconducting separators. Interesting results were obtained in all cases and the work is now pursued with an open-gradient cryogenic magnetic separator. Upon its completion, a comprehensive report will be issued for comparing the performance, efficiency and operating costs of the various machines. In-house wet magnetic treatment of a new coal (Donkin) is now underway.

(b) Deep cleaning of high sulphur coals

A literature survey on the petrography and mineralogy of Eastern coals was made to support and complement our work on their deep-cleaning by progressive grinding, flotation and magnetic separation. It was found that this novel approach to coal beneficiation behaved as predicted by the mineralogical data on grain size and liberation. The ash and sulphur minerals removed from the Lingan and Prince coals attained about 95%, thus giving coal products with less than 1% ash and sulphur (Lingan) and 2% ash and sulphur (Prince). A report was written on this subject matter for publication by AIME. Ultimate cleaning of the DEVCO Donkin coal is now underway and will be reported in the near future.

(c) Dry processing of coal

A low grade thermal coal was entirely processed by dry methods. Further to crushing (and grinding) and investigating several processes including jigging and tabling, magnetic and electrostatic separation, etc..., an integrated dry flowsheet was developed and tested with satisfactory results. It recovered 83% of the coal values (at 11,720 BTU/lb), while rejecting 62.5% of the ash-bearing minerals in some 29% of the weight. The latter, as well as the economy realised by dry treatment, will have considerable bearing on the possibility of processing and

shipping this coal from Alberta to eastern markets. A paper was written and presented at the CIM Meeting in Vancouver.

(d) Column flotation of ultrafine high sulphur coal

The quiescent conditions in the flotation column indicate that the method should be superior to the conventional mechanical flotation in selective separation of the relatively light coal from the heavier ash and pyrite. For the liberation of ultrafine pyrite from coal prior to their selective separation, a Szego-450 ultrafine grinding system was installed at the Victoria Junction Coal Preparation Plant of DEVCO, Sydney, N.S., where a 500 mm diameter flotation column is in use already. A test program for the selective separation of pyrite from coal using the flotation column following the ultrafine grinding of the high sulphur coal using the Szego-450 grinding system is in progress. Flotation feed of 10 microns is being prepared using the ultrafine grinding system. A series of preliminary studies indicated that ultrafine coal presents no serious problems in column flotation. Optimization of the circuit is now in progress.

(e) Selective biodepression of pyrite from coal

A preliminary study in the surface chemistry laboratory indicates that a novel biodepression technique can be utilized for the selective separation of pyrite from coal by rendering the surface of pyrite more hydrophilic, selectively from that of coal, through the adsorption of a microorganism called Thiobacillus ferrooxidans. Further investigations are being carried out in our laboratory as well as through a research contract awarded to the B.C. Research Council for the development of a large scale culturing technique of Thiobacillus ferrooxidans and for some bench flotation of coal from pyrite before and after treatment with the microorganisms.

(f) Development of the "CANMET Sulphur-Form Analyser"

A new simple quantitative analysis technique was developed for the determination of different sulphur forms (i.e. organic, pyritic and sulphatic) in coals. The present method utilizes the difference in the kinetics of SO_2 evolution from coal by different forms of sulphur. The method was patented through the Canadian Patent Development Limited on December 17, 1984. Considering the immediate potential impact of such a development, a three-year research contract is being arranged for the development of a prototype of the CANMET Sulphur-Form Analyser.

(g) Report:

- ERP/MSL 85-38 (OP)

(h) Contracts:

- Reqn. 4-9163 "Dry magnetic cleaning of fine coal", Sala Magnetics. S.A. - G.I. Mathieu.

- Reqn. 4-9164 "Dry magnetic cleaning of fine coal", Cryogenics Consultants Ltd. S.A. - G.I. Mathieu.

- Reqn. 4-9165 "Dry magnetic cleaning of fine coal", Eriez Manufacturing Co. S.A. - G.I. Mathieu.

- Reqn. 4-9189 "Selective biodepression of coal-pyrite from coal in flotation desulphurization of high sulphur coal", B.C. Research Council. S.A. - K.S. Moon.

- Reqn. 5-9143 "Desulphurization of Sydney coal by bacterial leaching", Atlantic Coal Institute. S.A. - R.G.L. McCready.

MINERAL PROCESSING SUB-ACTIVITY

Minerals Evaluation

- **Project 30.05.01:** Mineralogical Evaluation of Ores

  Project leader : P.R. Mainwaring

Objective:

To promote the development of Canadian mineral resources including various large tonnage, low grade and complex deposits of metallic minerals as well as known industrial mineral occurrences by detailed study and assessment of the mineralogy and liberation characteristics of such deposits and by preliminary laboratory studies directed toward the improved recovery and utilization of contained minerals.

(a) Final studies in the Buchans area of Central Newfoundland included completion of mineralogical and predictive optimum grind studies, using image analysis methods, of the Tally Pond base metal deposit. Bench test-work, confirmed by image analysis of the products, substantiated the problematic nature of this ore. A qualitative geological and mineralogical examination of the Tulks base metal sulphide deposit was also completed.

(b) Commissioning and programming of the automated, SEM-based image analysis system have been completed and data processing of large numbers of measurements on ores under program control is now possible. New applications include textural analysis and the complete characterization of uranium and base metal sulphide tailings, including mineralogy and proportions of minerals in different samples.

The first, annual Workshop on Image Analysis Applied to Mineral Dressing attracted about 30 participants from operating companies, universities and research organizations.

Fig. 1. Programming of the automated image analyser

(c) A study of mineralogy and recovery of base metal sulphides from problematic fine-grained, graphitic ores of Northern B.C. and Yukon has been initiated. Metal recoveries will be determined by automated image analysis.

(d) As part of the study the reasons for silver losses into jarosite precipitates, the effect of arsenic substitution for sulphur is being investigated. To this end, the structure of beudantite is being determined.

Two other mineral structures were completed this year. The first is that of ordered ancylite, a rare-earth, alkali-earth hydroxy carbonate. It was found that preferential ordering in certain crystallographic sites had occurred, and the reasons for this, and the implications of this in mineral separation are currently under study.

In the investigation of copper-ore minerals, the crystal structure of rosasite, a mineral structurally different from, but physically similar to malachite, has been determined.

(e) Contracts:

- Reqn. 5-9155 MDA "Selection of mineral deposits in Newfoundland suitable for research", Nolan, Davis and Assoc. S.A. - J.L. Jambor.

- Reqn. 5-9209 MDA "Evaluation of the Point Leamington Deposit, Newfoundland Phase I - Sampling", Nolan, Davis and Assoc. S.A. - J.L. Jambor.

- Reqn. 5-9216 MDA "Sampling and analysis of N.B. manganese deposit", Atlantic Analytical Services Ltd. S.A. - G.M. Ritcey.

- Reqn. 4-9235 MDA "To determine the mineralogical characteristics that affect recoveries of Cu, Zn, Pb, Ag, Au in Cu/Zn/Pb concentrate and ores from Manitoba", Hudson Bay Mining and Smelting Co. Ltd. S.A. - W. Petruk.

Beneficiation - Metallic

- **Project 30.13.01:** Mineral Processing Plant Simulation
  Project leader : R.F. Pilgrim

Objective:

To provide the mineral and coal industry with a user-friendly computer methodology for circuit and equipment optimization and design. This technology transfer is needed to allow the industry to fully use state-of-the-art methods of process optimization in times of increasing processing costs and decreasing grades in ore-bodies.

(a) During the period under review, a generalized splitter-mixer simulator was developed by E.A. Terheijden of the Computer Science Center, EMR, incorporating a convergence acceleration method to optimize the computation of complex circuits involving recycle loops. At the same time, standardized input argument lists were implemented for all unit simulators. These developments permitted the writing of three circuit simulator programs - for grinding, classification and for flotation circuits.

The SPOC manual, consisting of 18 separate chapters, was up-dated and republished to provide the supporting documentation for all the computer programs in SPOC.

With the cooperation of the Technology Information Division, CANMET, a system was established for disseminating SPOC information and for distributing chapters of the manual and software. Software may be obtained on magnetic tape either for the CYBER mainframe or for the IBM PC computer. The PC software is also available on individual diskettes.

To provide an on-line workshop for training new program users or to give prospective users the opportunity to test the SPOC software before purchasing it, a new interactive demonstration system was established. It may be accessed through telephone lines or through the DATAPAC system which is available across Canada. Default data are supplied to test each program, after which the user is prompted to enter his own data for all input variables.

Demonstrations of the SPOC system were made at the International Mineral Processing Software Exhibit at the 24th Annual Conference of Metallurgists in Vancouver, B.C., in August 1985 and at the Canadian Mineral Processors Conference in Ottawa in January 1986.

(b) Report:

- MRP/MSL 85-3 (OP&J)
- SPOC Manual (See Section D, p. 58)

(c) Contracts:

- DSS-23261-6-41409 "Conversion of SPOC software to micro computer", IOTA Consulting Ltd., Ottawa, Ontario. S.A. - E.A. Terheijden.

- DSS-23376-5-4779 "To provide consultation services for the SPOC project", Frederick Flament, Charlesbourg, Quebec. S.A. - R.F. Pilgrim.

- Reqn. 6-9013 MDA "Flotation process control", Sherritt Gordon Co. S.A. - K.S. Moon.

- **Project 30.13.02:** Iron Ore Processing
  Project leader : W.H. Cameron

Objective:

To identify methods for improving grade and quality of iron ore concentrates, quality of pellets, lessen environmental impact and improve process control.

Canada is well endowed with iron ore resources and policy makers have assumed that Canada will therefore remain a major supplier. However, in recent years it has become increasingly apparent, in a buyer's market, that Canada cannot assume it can compete in each and every market. High labour and energy costs have made pellets less attractive than sinter feed to a blast furnace. There is a need to improve efficiency, reduce energy input costs and improve product quality and recovery.

(a) Ore variability

A contract awarded to Geostat Systems Int. Inc. to do a detailed geostatistical study and to implement, on the basis of this study, a grade control program at Quebec Cartier's Mt. Wright concentrator has been extended to March 31, 1986, because of a delay in obtaining borehole data from U.S. Steel.

(b) Cold extruded pellets

No organic binders have been found to replace bentonite. Organic binders (0.25%) mixed with calcium carbonate (1%) have been used successfully but all show a drop in pellet strength at mid-temperature range 500°C. Some fully indurated pellets show greater strength than those made with bentonite. Problems have been encountered using Carol Lake concentrate because of magnetite. Cold bonding will be tried.

(c) Gravity studies

Problems have been encountered in getting the right pumping-conditioner system. Studies are underway to run Wabush rougher spiral tailings over the No. 7 Mineral Development spiral. Spiral concentrate is to be subjected to flotation for upgrading. The objective is to determine if additional iron units can be recovered from tailings.

(d) Spiral deposits or biofouling

An industrial problem that happens occasionally in spiral concentrate is the build-up of deposits on the spirals which destroy their configuration thus contributing to the middling. One such plant was identified and with their cooperation a sampling campaign was carried out by CANMET. Causes of the problem were identified and a report sent to the Company along with recommendations on how to correct it. These recommendations are now being carried out.

(e) Magnetic studies on diverse ores

Studies are being carried out. The objective is to pre-concentrate mill feeds by using an Eriez 7500 gauss rare earth rolls magnet.

(f) Low silica flotation studies

Various amine and reverse flotation studies have been carried out in an attempt to make low silica iron concentrates. Scavenging appears to be more effective than cleaning. The best results produced a high grade concentrate containing 1.5% silica at a recovery of 85% iron.

(g) Other activities

(i) At the request of the Industrial Energy Research Division an officer from CANMET spent several days at the Algoma Flotation Plant in Wawa. A report was sent to the I.E.R.D. Secretariat.

(ii) Meetings between an MSL Officer and the Department of Regional and Industrial Expansion are on-going regarding pollution abatement.

(iii) At the request of industry the Iron Ore Technical Task Force Committee has been reestablished with an MSL officer acting as chairman. Industry has requested two meetings a year; one in Ottawa in conjunction with the Canadian Mineral Processors Conference and one at the mine site in either June or September. The first meeting was held January 24, 1986.

(iv) A report is presently being written to supply Algoma Ore Division and Wemco Ltd. with additional information and calculations on densimetric curves originally done for Algoma under a START program.

(h) Reports:

- MRP/MSL 85-72 (IR)
- MRP/MSL 85-83 (IR)
- MRP/MSL 85-126 (TR)

(i) Contracts:

- Reqn. 4-9181 "Comparative study of geostatistical grade control and classical approach - iron ore processing", Geostat Systems Int. Inc. S.A. - W.H. Cameron.

- Reqn. 4-9259 "Development of a punchless operation of a Pierce-Smith converter", University of British Columbia. S.A. - M.C. Campbell.

- Reqn. 4-9316 MDA "Development of a technically and economically acceptable substitute binder for bentonite for use with Carol Lake Concentrates", Iron Ore Co. of Canada. S.A. - J.M.D. Wilson.

- Reqn. 5-9196 MDA "Increase of iron ore recovery", Wabush Mines. S.A. - M. Stefanski.

• **Project 30.13.03:** Design, Development, Evaluation and Commissioning of Scientific Equipment

Project leader : A.I. Stemerowicz

Objective:

To design, fabricate and test Continuous Process Development Unit (CPDU) equipment not available commercially; to test and evaluate the performance of equipment for mineral processing and to compare the performance of alternative equipment designs; and to commission other scientific equipment purchased for CANMET's laboratories.

(a) Industrial minerals mill

This project as it applies to the industrial minerals mill is being carried out in conjunction with other R&D projects. The following equipment was evaluated and commissioned.

(i) Jones Wet High Intensity Magnetic Separator - impurities were removed from samples of nepheline syenite, silica sand, talc and kaolin.

(ii) Sturtevant 4-inch Micronizer was tried for grinding/classifying talc, calcite and quartz to 10 µm and finer.

(iii) Wemco Heavy Media Separator - trials for separating barite from dolomite/silica were carried out. In the last trial a biopolymer was added to the media suspension and was found to be effective in helping to stabilize the suspension. Further tests on barite and on gypsum/anhydrite samples will be carried out.

(iv) Walther Air Classifier - a preliminary evaluation was carried out using minus 50 µm silica and talc and minus 70 µm barite to determine the separation cut point size for each mineral. For silica and talc the cut point size is approximately 11 µm and for barite it is approximately 5 µm. Based on this study the ability of the classifier to sharply separate minerals into coarse and fine fractions was only fair.

(v) Bahco Micro Particle Classifier - this unit which can classify down to minus 1 µm was calibrated using minus 50 µm barite and silica.

(vi) Micromeritics Sedigraph 5000 D - this particle size analyser was tried for the size analysis of ground samples of talc, calcite and silica.

(b) Chemical Laboratory

A Perkin-Elmer 8310B gas chromatograph was purchased and commissioned. It is to be used mainly for analysis of organic solvents and organometallics.

(c) Extraction Metallurgy Laboratory

Two columns were installed to study weathering of sulphide and uranium tailings under a column of water. The objective is to determine whether underwater disposal is more desirable from an environmental point of view than surface disposal open to the atmosphere.

The columns which are 6.1 m high are fabricated from 2-ft diameter (61 cm) PVC pipe and contain 0.25 t of tailings. Provision is made to monitor dissolution of chemical components and stability of bacterial population.

(d) Reports:

- MRP/MSL 85-80 (TR)
- MRP/MSL 85-133 (TR)

(e) Contracts:

- Reqn. 5-9230 MDA "Evaluation of equipment and processes to dample offshore placer deposits from small fishing vessels", Nordco Limited. S.A. - D.M. Doyle.

• **Project 30.13.04:** Improved Recovery Technology of Fine Particles and Tin

Project leader : M.A. Cristovici

Objective:

To investigate methods to improve the recovery of fine mineral particles; to develop methods for the recovery of tin from base metal sulphide flotation tailings that are more efficient alternatives to the inadequate gravity concentration methods now in use.

Tin occurs in varying amounts in many Canadian base metal sulphide ores. Three operations in particular, Kidd Creek Mines, Brunswick Mining and Smelting Corp., Ltd., and Health Steele lose over 7000 t/a of tin worth about $90 million. Only Kidd Creek has a tin recovery circuit utilizing state-of-the-art gravity concentration, but operations have been suspended because the very low tin recoveries obtained (less than 10%) do not cover operating costs. Even the development of a method for recovering only a modest 30 to 40% of the tin in the tailings would result in a substantial increase in economic return.

Preliminary work was first carried out to identify the problems of processing fine particles and to outline the directions of investigation. Modern methods to process the fine particles were reviewed and a search for suitable samples was conducted.

Based on this work the following samples and methods were selected for this investigation:

- Tantalum ore for selective flocculation and Nagahm flotation with fine dispersed air bubbles;

- A complex sulphide ore for microfoam flotation;

- Brunswick Mine and Kidd Creek ore tailings for tin recovery work.

Research work was then initiated to study the chemico-physical and mineralogical characteristics of the samples and to develop recovery methods for fine particle minerals.

Mineralogical studies revealed that in Tanco ore only 20% of the tantalum minerals (wodgenite and microlite) were liberated, the rest being associated with feldspar and quartz. Mineralogical work on the other samples is in progress.

(a) Selective flocculation and Nagahm flotation grinding tests were carried out followed by mineralogical and chemical analysis to determine the required conditions for an advanced liberation of tantalum minerals.

It was found that the ore must be ground to 82% -20 micrometres to obtain a 92% liberation of the tantalum minerals. Separation of relatively pure tantalum minerals was then initiated in heavy liquid or by superpanner, magnetic separation, etc. to obtain individual mineral species which can be analysed for their surface characteristics and response to selective flocculation. The equipment set-up for testing is almost completed with the exception of the Nagahm flotation cell which could not be procured yet.

(b) Microfoam flotation unit

A microfoam generator was designed and fabricated from polycarbonate rod. The principle of operation is similar to that of an aspirator filter pump except that air entry to the throat of the venturi is severely restricted. The result is the formation of very tiny bubbles (about 50 µm in diameter) as the solution is pumped through the device. In preliminary tests the microfoam generator produced the required bubble size. The main problem encountered was the coalescence of the very small bubbles to form much larger bubbles with a lower surface:volume ratio. To prevent coalescence, flotation feed must be as fine as possible, preferably 5 micrometres. A new flotation tank has been built for the microfoam flotation unit but has as yet not been tested.

(c) Flotation technique to separate cassiterite from sulphides

Standard tin flotation practice is to first float the sulphides before attempting cassiterite flotation. On Canadian base metal tailings such as BMS this is not feasible because of the very high (80-90%) sulphide content. Therefore it is essential to develop a technique to float cassiterite away from the sulphides. A promising method is to employ nascent hydrogen produced by electrolysis as a sulphide depressant. To this end an electro-flotation cell has been designed and was fabricated by TSD. Currently the flotation of pure tin powder using sulfhydryl collectors at a range of pH's is being investigated. Research strategy is to convert the cassiterite surface to metallic tin to make it amenable to flotation with sulfhydryl/collectors.

The other line of investigation is to recover tin from Kidd Creek tailing by using new developed reagents, specific for tin flotation.

A dispersant and a collector recently developed and experimented abroad with good results for tin flotation were procured and will be tested soon.

(d) Contracts:

- Reqn. 4-9178 "Investigation of electrical properties of bubbles as they affect the flotation of fine cassiterite", COMINCO Ltd. S.A. - A.I. Stemerowicz.

- Reqn. 5-9030 MDA "To develop S^2 reducing mineral beneficiation techniques and perform S^2 emission tests of Inco smelter, Thompson, Manitoba", Inco Ltd. S.A. - W. Craigen.

- Reqn. 6-9012 MDA "Column flotation - cleaning of zinc rougher and scavenger concentrate", Sherritt Gordon Co. S.A. - K.S. Moon.

- **Project 30.13.05:** Liberation/Flotation Models
  Project leader : W. Petruk

Objective:

The objective of the project is to develop a liberation model which predicts the mineral liberations that would be obtained at different grinds for different types of ores, and to

incorporate the predicted data into grinding and flotation models which have been developed at CANMET by the SPOC program. Several liberation models, based on the size distributions of minerals in unbroken ores, have been proposed, but in some instances the predicted liberation does not correspond to the observed liberation.

(a) The work plan is to generate a large amount of data with the image analyser in the Process Mineralogy section by determining size distributions of minerals in a variety of unbroken ores, and measuring mineral liberations in mill products obtained from these ores. When enough data are collected correlations will be made between predicted and observed liberations to determine which parameters have an effect on mineral liberations. These parameters will be incorporated into a liberation model and the new liberation model will be incorporated into existing grinding and flotation models.

An interpretation has been made of the data collected to date and a paper submitted for publication in Process Mineralogy IV which will be published by A.I.M.E. Close correlations were observed between predicted and measured liberations for most minerals in most ores, but not for galena, cassiterite and occasionally chalcopyrite in base metal ores, nor for chalcopyrite lamellae in sphalerite. It was interpreted that liberation is controlled by the breakage characteristics of the host mineral as well as the size distribution of the wanted mineral. The logic is that if the host mineral breaks into the same sized particles as the size distribution of the ore, the observed liberation will correspond to the liberation predicted by models based on size distributions of the mineral. If on the other hand, the host mineral breaks into smaller particles, the observed liberation will be higher than predicted. The hypothesis that liberation is dependent upon the host mineral will be tested further, and numerical breakage factors for each mineral will be developed. These will form the basis for a working liberation model.

(b) Contract:

- Reqn. 4-9232 "Mineralogical studies of potash deposits", New Brunswick Research and Productivity Council. S.A. - W. Petruk.

Beneficiation - Industrial Minerals

- **Project 30.21.01:** Energy Conservation in Industrial Mineral Processing
  Project leader : G.W. Riley/F.R. Campbell

Objective:

To increase the energy efficiency of existing industrial systems and to develop technologies to reduce the energy content per unit of production in the industrial mineral sector.

The industrial minerals sector spends more money on energy as a production input than any other industry, spending about 12 cents out of every dollar overall, nearly four times the average for the manufacturing sector as a whole. In certain industries, such as cement, lime and gypsum, energy costs represent about one half of production costs. While the situation has improved somewhat since the days of cheap oil (a 15% reduction in energy input per tonne of output), this was largely obtained simply through better housekeeping and the elimination of obviously wasteful practices. Further improvements require improved equipment design, process modification, fuel switching, use of less energy intensive materials as supplements and the optimization of energy flows. All of these require R&D to optimize processing conditions.

This project includes work in three main areas: a) comminution, b) firing of clay products, and c) use of supplementary cementitious materials in concrete.

This program is supported largely through the federal energy R&D program under the Panel on Energy R&D. Most of the work is being carried out under contract although some work under c) involving the use of ferrous and non-ferrous slags is undertaken in-house.

(a) Comminution

Reducing the size of the as-mined materials to meet processing or end use requirements represents the major component of energy input in the processing of many industrial minerals. This element of energy and dollar cost can be reduced through improved grinding techniques plus much closer control of the degree of grinding.

Contracts:

- Reqn. 4-9037 "Energy conservation by chemical comminution of Asbestos Phase II", Ontario Research Foundation. S.A. - D.M. Doyle.

This project continued throughout the reporting period, comparing the potential for energy savings in utilizing the wet (with and without surfactants) grinding process for asbestos rather than the conventional dry process. Results are very positive. The wet process, especially without surfactants, is capable of greater productivity at reduced energy, capital and operating costs while improving product recovery and quality.

- Reqn. 4-9263 "Energy conservation in comminution of Industrial Minerals Phase III: Development of pilot plant systems", Canada Cement Lafarge Limited. S.A. - D.M. Doyle.

Earlier phases of this project developed a database on current comminution methods for 10 common industrial minerals, and established a monitoring methodology for control of comminution circuits. Phase III got underway during 1985/86 and will

develop, on the basis of pilot plant tests, a detailed statement of technical requirements for implementing state-of-the-art comminution technology in the Canadian minerals processing industry.

(b) Firing of clay products

The firing of clay products is a high temperature industrial process which utilizes large amounts of energy. Improvements which increase the thermal efficiency of this process or reduce the firing temperature or time can result in substantial energy savings.

Contracts:

- Reqn. 3-9079 "Effect of fluoride emission controls on the energy efficiency of tunnel kilns manufacturing structural clay products Phase II", Pollutech Limited. S.A. - K.E. Bell.

The use of scrubbers to control fluoride emissions on existing kilns reduces the thermal efficiency of the kiln's heating process. The first phase of this study identified different firing schedules and/or additives which would also reduce fluoride emissions. Phase II is conducting initial tests on these alternatives prior to proceeding with in-plant testing which will comprise Phase III.

- Reqn. 4-9167 "Development of once-fired ceramic giftware Phase II", Blue Mountain Pottery Limited. S.A. - K.E. Bell.

Blue Mountain was to develop a new ceramic mix and a new means of applying a decorative finish which would permit the product to be fired only once rather than the two or three firing cycles currently required. Unfortunately, as a result of the failure of the contractor's business, this contract was terminated prior to completion.

- Reqn. 5-9186 "Energy conservation in investment casting using Canadian industrial minerals Phase II", Designed Precision Castings Inc. S.A. - K.E. Bell.

In an earlier phase, the contractor identified potential new refractory blends which would allow a much lower firing temperature in their manufacture of molds for casting Al/Cu alloys. Phase II began in October 1985 to optimize the refractory blend and to demonstrate the advantages of this blend in their plant. This phase is scheduled for completion in March 1987.

(c) Supplementary cementing materials

The manufacture of cement is especially energy intensive (grinding and calcining). A number of largely waste materials (fly ash, condensed silica fume, ferrous and non-ferrous slags) can substitute in part (up to 50%) for the cement in many concrete applications without major processing requirements. This program seeks to develop and demonstrate such supplementary cement materials (SCM). The majority of the work is contracted but in-house studies have examined the physical characteristics of the supplements and of the resultant concretes.

Reports:

See project 30.37.01

Contracts:

- Reqn. 2-9200 "Utilization of Canadian pozzolanic materials in reducing the effects of alkali-aggregate reactivity", Canada Cement Lafarge. S.A. - J.A. Soles.

The use of supplementary cementing (pozzolanic) materials can allow greater use of alkali aggregates in concrete without the deleterious effects of alkali aggregate reactivity. Another benefit is that such concretes do not exhibit as much expansion as they cure. This contract will conduct tests (some of them long term durability tests) on a wide range of concretes utilizing SCM's.

- Reqn. 3-9227 "Production and evaluation of blast furnace slag from Algoma Steel's furnace for possible use an an additive to concrete", W.M. Watts Engineering Limited. S.A. - E. Douglas.

A process has been developed to produce a desirable SCM from blast furnace slag. The product slags and concretes made from substituting this slag for varying amounts of cement have been subjected to round robin testing. The contract has led directly to the construction of a major production facility in the Algoma area (see Highlights).

- Reqn. 4-9174 "Characterization of granulated blast furnace slag for portland cement replacement in concrete", Ontario Research Foundation. S.A. - E. Douglas.

This contract has completed certain detailed evaluations and characterization of the slags and concretes referred to above.

- **Project 30.21.02:** Beneficiation/Grinding Studies - Selected Minerals
  Project leader : R.K. Collings

Objective:

To develop and improve processing methods for the recovery of minerals and mineral products acceptable to specific markets from selected industrial mineral deposits, and including improved methods for the production and classification of ultrafine mineral material for specific applications, notably the filler/extender market.

Concern by both government and industry regarding present and future resources of industrial minerals, increased exploration, development, pro-

cessing and energy costs, more stringent product specifications, more diverse and developing applications and markets, and competition in and for these markets, have focussed attention on the need for more information on our resources and their potential for development, for more efficiency in production and processing, and for greater diversity in product development to maintain a competitive edge in domestic and international markets. This project has been developed in response to this concern. Work in progress during the review period include studies on silica, barite, potash, kaolin, asbestos, and on fine grinding and classification of minerals.

(a) Silica

Work on the third and final phase of this study, incorporating beneficiation studies of samples from deposits in Nova Scotia, New Brunswick, Manitoba, Saskatchewan, Alberta and British Columbia, was essentially completed during the review period. Processing/beneficiation essentially consisted of stage crushing and sizing following by attrition scrubbing, washing, flotation, magnetic separation and acid leaching, the objective being to produce both glass- and foundry-grade sand. A full report is in preparation. An extension of the completed Ontario/Quebec studies, the wet 'attritor' grinding and processing of Potsdam sand, is planned to investigate the production of a rounded-grain sand for use by the foundry industry.

A study 'Nova Scotia Silica Study' carried out under the Canada/Nova Scotia Mineral Development Agreement provided background information and samples for study from a number of silica deposits. A report on the work has been prepared.

(b) Barite, celestite, fluorite

Background information and reports of potentially economic deposits of the noted three minerals in, particularly, Newfoundland, Nova Scotia, Ontario and British Columbia were reviewed. On the basis of this review, laboratory studies were/are essentially confined to barite. Processing was essentially restricted to wet and dry gravity methods of separation, the objective being to produce a 'mud-grade' product of 4.2 S.G. Work under START provided R&D information on two B.C. deposits and under the Canada/Nova Scotia MDA, information and samples for laboratory study from four N.S. deposits. Work is continuing on upgrading barite-containing tailings from Buchan's, Newfoundland, and ore/tailings from Scotsville, N.S. Samples from two Ontario deposits Hemlo (tails) and Matachewan will be included in the overall study with a final report being scheduled for 1986/87. An interim report has been prepared.

(c) Potash

Studies of the surface chemistry reactions of sylvite/halite in flotation using dodecyl ammonium chloride are continuing in an effort to improve recovery of and grade of sylvite (potash). Additionally a contract has been let to study dry separation methods, especially electrostatic, for the separation of these two minerals. A recent in-house study indicated some upgrading of sylvite/halite by dry magnetic separation.

(d) Kaolin

A preliminary study of the evaluation of Black Island, Manitoba, kaolin as source material for paper filler was initiated. Further detailed work is planned.

(e) Asbestos

A contract to investigate the chemical defibrization of asbestos fibre (Ontario Research Foundation) will soon be completed and the report made available to interested parties.

(f) Fine grinding/sizing

Work continued re grinding/classifying of talc/calcite/quartz (hardness 1/3.5/7) with several new units, a jet mill, attritor grinder, microparticle classifier, and sedigraph being incorporated in the study. A preliminary report of this work is in preparation.

(g) Contracts:

- Reqn. 4-9232 MDA "Mineralogical studies of potash deposits", R.P.C. New Brunswick. S.A. - W. Petruk.

- Reqn. 4-9234 MDA "Energy conservation gypsum wallboard literature review", Ontario Research, completed. S.A. - R.K. Collings.

- Reqn. 5-9059 MDA "N.S. barite study deposits/activity/problems", Jacques Whitford, completed. S.A. - R.K. Collings.

- Reqn. 5-9061 MDA "N.S. silica study deposits/activity/problems", Fenco Shawinigan, completed. S.A. - R.K. Collings.

- Reqn. 5-9079 MDA "Laboratory and pilot plant study on electrostatic separation of potash ore", Potash Corporation of Saskatchewan. S.A. - K.S. Moon.

- Reqn. 5-9094 "Technical review and development of preliminary capital and operating cost estimate comparison of asbestos wet and dry milling processes", Kilborn et Associés Ltée. S.A. - D.M. Doyle.

- Reqn. 5-9242 MDA "Three chromite ore bulk samples from Bird River", Grewinski Trucking, completed. S.A. - P. Andrews.

- Reqn. 5-9246 MDA "Upgrading of feldspar", Tantalum Corp. Bernic Lake, Manitoba. S.A. - P. Andrews.

Treatment - Ceramics

- **Project 30.29.01:** Electrical Energy Storage Devices
  Project leader : T.A. Wheat

Objective:

To develop the technology for the fabrication and exploitation of various solid-state electrolytes in energy storage and conversion applications and to demonstrate their most promising applications through technology transfer.

(a) Development of beta"-aluminas for use in energy storage and conversion

During the past year, the electrical and microstructural properties of spray-dried beta/beta"-aluminas containing various levels of Li^+ and Mg^{2+} stabilizer have been determined using materials produced both in-house and also at Almax Industries Ltd., Lindsay. The object is to determine the compositional latitude that may be tolerated on a production line to still yield an acceptable product.

(b) Development of isotropic conductors

Little further work was conducted on the isotropic sodium-conducting silicate systems that were reported in the previous period. Their instability to liquid sodium above 280°C renders them unsuitable for their intended application as second generation materials displacing beta"-alumina in either thermoelectric generators (Almax Industries Ltd.) or the sodium-sulphur battery (Powerplex Technologies). However, work has continued on the hydrogen-conducting analogues under project 30.29.02.

(c) Non-destructive evaluation of solid electrolytes

The development of techniques to detect small sub-surface flaws in sintered ceramic is important if the material is to be stressed electrically and/or mechanically. During the present period, development has continued under contract to McMaster University and in collaboration with BM Hi-Tech Inc., Collingwood to lower the limit of detection of fine defects in ceramic using ultrasonic techniques. Commercial transducers can typically detect 75 micrometre defects; using custom-made transducers produced under CANMET contract ~25 micrometre defects can be detected. During the present period, the ability to produce transducers operating over 50 MHz with a focussed beam of any focal length has been developed and used to characterize the changing microstructure that occurs on ion ion-exchanging solid electrolytes to produce hydrogen-conducting materials (see 30.29.02).

(d) Development and demonstration of a small-scale commercial thermo-electric generator

This four-year program, due for completion in March 1986, has been conducted by Almax Industries Ltd. under the PILP program with assistance from CANMET to demonstrate a small-scale thermoelectric generator producing electric power directly from any heat source such as an industrial stack.

Interest in using these devices for remote power sources has been expressed ranging from the cathodic protection of transcontinental gas pipe lines to space applications.

(e) Technical support given other departments funding R&D in solid electrolytes

Because of CANMET expertise, technical advice as a scientific authority has been given to various sectors of EMR and NRC for the following contracts dealing with solid electrolytes:

- Hermetic seal technology (Quality Hermetics, Toronto); NRC, IRAP.
- High purity alumina and toughened zirconia (Home Technics, Peterborough); NRC, IRAP.
- Microwave ceramics (Almax Industries, Lindsay); NRC, IRAP.
- Boron nitride composites (Electrofuel, Toronto), DSS/EMR, UP.
- Ultrasonic transducers and materials (BM Hi-tech, Collingwood) NRC, IRAP.
- Injection moulding ceramics (Lakeside Electronics, Whitby); NRC, IRAP.
- Sodium-sulphur battery development (Powerplex, Markham); EMR, IERD.
- Surface acoustic wave filters based on thin-film piezoelectric ceramics (Almax Industries, Lindsay); NRC, IRAP.

(f) Reports:

- ERP/MSL 85-22 (OP)
- ERP/MSL 85-24 (OP)
- ERP/MSL 85-31 (OP)
- ERP/MSL 85-35 (OP)

(g) Contracts:

- Reqn. 3-9130 "Development of nondestructive testing techniques for the evaluation of sintered solid electrolytes - Phase III", McMaster University, completed July 1984. S.A. - T.A. Wheat.
- Reqn. 4-9114 "Characterization of solid electrolytes", McMaster University, completed Oct. 1985. S.A. - A.K. Kuriakose.
- Reqn. 4-9175 "Nondestructive testing of electrolytes", McMaster University. S.A. - T.A. Wheat.

• **Project 30.29.02:** Project to Develop a Hydrogen-Air Fuel Cell
Project leader : T.A. Wheat

Objective:

To develop and exploit a hydrogen-conducting solid electrolyte in a hydrogen-air fuel cell and to demonstrate the technology by transfer to industry.

(a) Development of equipment to determine the dielectric properties of materials

Essentially, two facilities have been established: one for the ac characterization of solid electrolytes and other solid dielectrics and one for the dc characterization of cells and electrode/electrolyte interfaces.

The first system is completed but the second system has been delayed by extended delays in equipment procurement. It is intended that the system will allow the characterization of solid electrodes operating in a solid electrolyte-based hydrogen-air fuel cell operating at controlled temperatures with controlled partial pressures of fuel and oxidant. During the present period, the system has been partially "hand-wheeled" in which the partial pressures of gases were automatically controlled but no automatic temperature control was possible.

(b) Development of solid electrolytes

All the hydrogen-conducting materials developed under this program by either CANMET or its contractors have been derived from the ion-exchange of a suitable sintered material (such as Na/K beta/beta"-alumina, gasicons, yasicons and zirpsios). Despite attempts to more closely match the lattice spacing of the precursor with that of the final product, there is always an inherent expansion that occurs and which seriously weakens the material (or fractures it).

During the present period, an alternative route has been developed at CANMET in which the powder form of the precursor is first ion-exchanged (thereby avoiding any gross strain) and then bonded using various suitable hydrogen-conducting materials. Using this approach, a number of hydrogen-conducting electrolytes based on various zirpsios and beta-aluminas have been produced and shown to have high conductivity and a much higher strength than materials produced from sintered bodies. A patent application has been filed for the process.

(i) Beta-Aluminas

The effect of a very low concentration of Mg^{2+} within an Al_2O_3 raw material catalysing the formation of single-phase beta"-alumina was reported earlier. This pre-treatment and the ready conversion to pure, highly conducting beta"-alumina using conventional processing equipment coupled with the use of a bonding process for the production of strong highly conducting hydronium electrolytes has been demonstrated during the present period.

(ii) Zirpsios

Similar progress has been made with this series of materials as reported above for the beta"-aluminas. Several hundred small discs 2.5-cm in diameter have been produced and shown to exhibit conductivities up to 10^{-3} $(ohm.cm)^{-1}$ at 100°C. Although these bonded materials exhibit nearly an order of magnitude higher strength than the earlier products, they are still not fully dense. The residual porosity is undesirable as the material should ideally be hermetic - future processing R&D will concentrate on minimizing any residual open (connected) porosity.

(iii) Gasicons and Yasicons

Contract work to McMaster University to produce these materials was terminated during the present period. Unfortunately, the needed high conductivity phase is only formed with difficulty and it is not clear that these materials would offer a significant advantage over either the zirpsios or the beta-aluminas above.

(c) Reports:

- ERP/MSL 85-9 (IR)
- ERP/MSL 85-26 (OP)
- ERP/MSL 85-149 (IR)

(d) Contracts:

- Reqn. 4-9114 "Characterization of solid electrolytes", McMaster University, completed. S.A. - A.K. Kuriakose.

- Reqn. 4-9203 "Synthesis of hydrogen-conducting solid electrolytes", McMaster University, S.A. - A.K. Kuriakose.

- Reqn. 4-9204 "Development of electrodes for solid electrolytes - Phase II", Queen's University. S.A. - T.A. Wheat.

- Reqn. 4-9223 "Characterization of thin films used as electrodes in electrochemical devices", Ontario Research Foundation. S.A. - T.A. Wheat and J.D. Canaday.

- Reqn. 5-9212 "Plasma sprayed perovskite material for electrochemical cell electrodes", Technical University of Nova Scotia. S.A. - J.D. Canaday and A. Ahmad.

- **Project 30.29.03:** Semiconductor Materials for Photoelectrochemical and Catalytic Processes

Project leader : S.M. Ahmed

Objective:

To develop semiconductor catalysts and photochemical processes with novel applications. These applications include: 1) oxidation and removal of pollutants such as CN^-, $S_2O_3^{2-}$ and SO_3^{2-} from metallurgical effluents; 2) conversion of CH_4 in natural gas to liquid hydrocarbons; and 3) other novel applications such as photoelectrolysis of water, photoelectrochemical dissolution of minerals and photochemical activation of minerals for flotation.

(a) Semiconductor electrode materials

Work has continued during 1985 towards development of improved semiconductor electrodes, mainly Fe_2O_3 and GaAs with thin Co films, for photoelectrochemical (PEC) processes.

It was found that Co films electrodeposited on GaAs up to 10 nm in thickness not only improve the PEC properties but also prevent photocorrosion. Attempts are being made to deposit more uniform Co films by magnetron sputtering. During the course of this work, ohmic contacts for GaAs for low and high temperature applications were developed and applications were filed for patents.

Fe_2O_3 is known to be a stable semiconductor with a medium band gap of 2.2 eV. However, unfavourable solid state properties such as the presence of trapping and recombination centres and surface states within the band gap make the PEC processes very inefficient.

Naturally occurring specular hematite was found to be a degenerate semiconductor but develops photocurrents after heat treatment in air. The nature of surface states and traps have been investigated by sub-band gap photocurrent and photoluminescence spectroscopy and impedance measurements. However, Fe_2O_3 has been found to be much more efficient as a photoanode for the oxidation of organics such as pyrogallol than for water oxidation (~20 times) by the photogenerated holes. Hence, Fe_2O_3 semiconductors could hopefully be employed for the PEC oxidation and oligomerization of CH_4 in non-aqueous strongly acidic medium.

As a next phase, Fe_2O_3 films, will be prepared by magnetron sputtering to obtain improved solid state properties and tried for carrying out PEC oxidation of organics including CH_4.

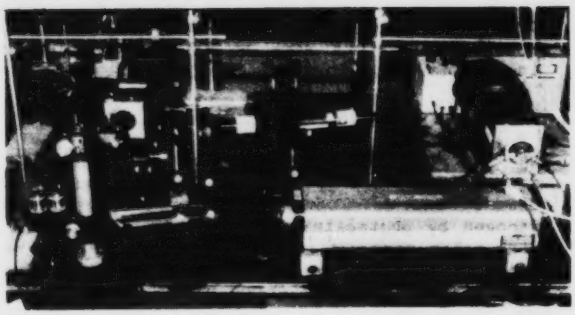

Fig. 2. Luminescence spectroscopy of semiconductor of electrode surfaces using He-Cd (442 nm) and He-Ne (633 nm) lasers

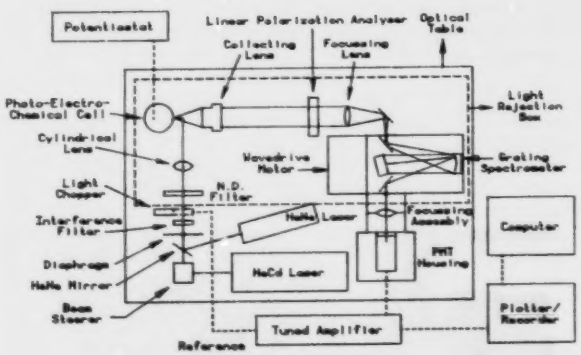

Fig. 3. Luminescence spectroscopy system

(b) Photoelectrochemical processes

A photoelectrochemical cell for studies of CH_4 condensation in superacids, coupled with a gas chromotograph, is being set up. Photoelectrochemical oxidation of propane and radical

formation by holes on semiconductor photoanodes in non-aqueous acidic medium has already been demonstrated separately in contract work at Simon Fraser University.

Work on preparation of semiconductor powders and certain exploratory work on PEC dissolution of minerals is about to start.

(c) IEA program

CANMET's participation has continued in the International Energy Agency (IEA) program of research and development for the production of hydrogen by photocatalytic electrolysis of water using solar energy (Task VI). Work at MSL on the photoelectrochemistry of semiconductors has been submitted to the IEA (Task VI) and in return CANMET has received current reports of work in other participating countries in this field.

(d) Report:

- CANMET 84-15

(e) Contract:

- Reqn. 3-9114 "Investigation of semiconductor catalysts for the production of liquid fuels", S.R. Morrison, Simon Fraser University, Burnaby, B.C. S.A. - S.M. Ahmed.

This contract ends in March 1986. Several papers have been published and bi-monthly reports are available.

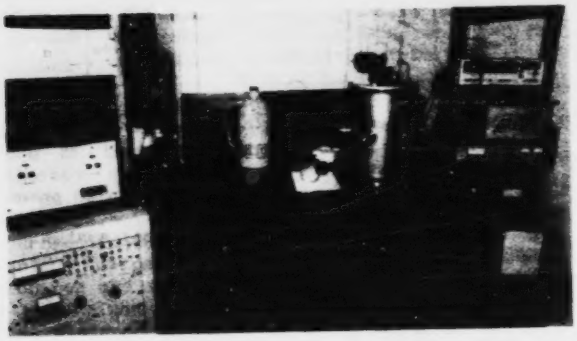

Fig. 4. Magnetron sputtering equipment for deposition of metal on semiconductor films by reactive sputtering

- **Project 30.29.05:** Electrodes and Refractories for the Steel Industry

Project leader : K.E. Bell

Objective:

To determine the nature and mechanisms of failure of slag-zone and metal-zone refractories for VOD (Vacuum Oxygen Decarburization) and VAD (Vacuum Argon Degassing) ladles, and to report on specifications of modified or alternative materials. The electrode work aims to establish practical methods for evaluting measurable properties of carbon electrodes and refractories that could be related to their performance in operation and applied as acceptance standards for the materials. This project also satisfies an expressed desire on the part of the steelmakers for an "independent" source of information beyond that of their suppliers, without necessarily implying lack of confidence in the suppliers, who are a continuing source of advice.

(a) The steel industry is adopting electric arc-furnaces technology. The high-powered units employed are efficient melters but are under-employed if used for secondary steel-making operations, which are increasingly being performed in ladles and associated transport vessels in a variety of processes. These intermittently operated vessels are subject to thermal shock, and to increased temperatures, more aggressive slags, vacuum, oxygen blowing and gas stirring, leading to short lifetimes of the refractory linings owing to corrosion, erosion and spalling. Among those recording the shortest lifetimes are ladles used in the VOD and VAD processes for making high alloy specialty steels, even though the best state-of-the-art refractories available have been selected on a cost-benefit basis.

With the cooperation of Atlas Steels Company, the mechanisms of degradation of the lining of VOD/VAD vessels are being determined. At the company's Welland plant, erosion and slag corrosion are the principal causes of reduced lining life. Spalling, possibly due to thermal shock, also occurs but the spalls tend to remain in place, not seriously affecting the integrity of the lining. At the company's Tracy plant the situation is further exacerbated by the production of titanium-bearing alloys and the use of more aggressive (more acid) slags, resulting in increased corrosion/erosion. In addition, these slags result in a zone of dicalcium silicates forming behind the exposed face. As gamma dicalcium disilicate decrepitates on cooling this zone is weakened and stressed, leading to spalling either directly or through reduced resistance to thermal shock.

Previous work at CANMET has revealed an inherent deficiency in the chrome-magnesia bricks used to line these vessels; they are subject to vaporization of the constituents into vacuum at high temperatures. The resultant increased porosity of the bricks allows increased slag penetration, shortening the life of the lining. As a result, in this review period the company has been conducting trials with alternative refractory materials, which CANMET has been examining in the laboratory as an aid to selection of the most appropriate replacement materials.

Four types of bricks were examined as replacement for the chromemagnesia bricks in linings: pitch bonded dolomite, tar bonded dolomite, resin bonded dolomite, and tar impregnated direct bonded dolomite. Vaporization of the constituents was primarily confined to the organic binders. The bricks were judged highly resistant to thermal shock (the expansile stresses are presumed to be taken up in the compressible bond material). Degradation appeared to comprise removal of the bond, with resultant erosion of the refractory grains, which subsequently dissolve in the slag. There is little or no slag penetration of the joints. The resin bonded material was judged the best performer and recommended for use. A report is in preparation.

Magnesia/carbon bricks with two levels of graphite flake are under examination as replacement for fusion-cast chrome-magnesia. High rates of vaporization of MgO will probably preclude their use in vacuum, but they appear likely to be well-suited to applications in hot spots of the electric-arc melter. A report will be issued early in FY 86/87.

Two sizes of high-alumina bricks used in the pour-pads of the ladles were examined for differences recorded in behaviour in service. No significant differences in composition, microstructure or slag resistance were found. The problem was concluded to be in brick size and geometry, and it was recommended in the report that the bricks be laid in mortar (to seal the joints) rather than dry.

(b) A comprehensive evaluation of the physical, chemical and electrical properties of carbon electrodes for arc-furnaces, and their methods of measurement, was completed early in the review period. No direct correlation between individual properties and service could be found. However, sonic pulse velocities reflect the sum of most physical properties such as density, strength, porosity, and will reveal major internal flaws. Simple eddy-current methods correlate with electrical conductance/resistance measurements. Both have the advantage of being non-destructive methods. The report recommended they be examined in-plant to verify correlation with electrode consumption and thus their utility as acceptance test methods.

No funding was available in the review period for a proposed contract with a steel producer to perform such evaluation. The contract will be pursued next year.

(c) Reports:

- MRP/MSL 85-70 (IR)
- MRP/MSL 85-128 (IR)

Treatment - Industrial Minerals

- **Project 30.37.01:** Performance and Durability of Concrete Incorporating Supplementary Cementing Materials

  Project leader : V.M. Malhotra

Objective:

To develop data on mechanical and elastic properties and durability of portland cement and portland cement concrete incorporating up to 65% less energy intensive materials, such as granulated blast furnace (B.F.) slag, fly ash, silica fume and limestone dust for applications in Canadian marine environments and in acidic waters of northern Canada; to develop a data base on portland cement concrete and portland cement/B.F. slag/fly ash concretes for industrial applications involving exposure to sustained temperatures in the range 75-450°C for periods up to six months; to produce a low cost asbestos cement cooling tower fill resistant to corrosion in extreme environmental conditions such as freezing and thawing, soft and brackish waters, corrosive water and abrasion.

To conserve resources and energy it is imperative that less costly and less energy intensive materials be used in the production of portland cement and portland cement concrete. The most promising of the less energy intensive materials for replacing cement are granulated slag, fly ash and silica fume. The energy required to produce granulated slag is estimated at only 25% of that for portland cement, and fly ash and silica fume are industrial byproducts. As slag and fly ash from different sources have unique properties depending upon the raw materials used, it is essential that investigations be performed to obtain long term performance data on their use, with and without high-range water reducers, in concrete under Canadian climatic conditions.

(a) Laboratory work was continued on the development of long-term data on the performance of concrete incorporating supplementary cementing materials. Several reports were issued during the years on the above research and these included relative performance of Canadian fly ashes in concrete, characterization and evaluation of a new granulated blast furnace slag, development of heat during cycles for portland cement/fly ash concrete for the precast industry. The studies dealing with slag and associated contract-out work has resulted in the establishment of a thirteen million dollar ground granulated slag facility in Northern Ontario.

The study continued in the evaluation of concretes containing different aggregates and cementing materials. A series of concrete mixes were made using lightweight aggregate and incorporating silica fume. The specimens were exposed to temperatures of 150° and 300°C for various periods of time. The mechanical properties of the specimens were determined before and after exposure. Data has been collected and a report is under preparation.

An IRDC/CANMET joint research project was initiated in 1986. The purpose of the project is the development of data base for fly ashes from Argentina and Canada. Under the Program, one of the research scientists from Argentina spent 4 months at CANMET.

A comprehensive state-of-the-art report on the use of fly ash in concrete has been prepared and it is in the process of being printed for publication as a CANMET monograph.

Under contract, research is being performed to develop a durable low cost asbestos cement cooling tower fill using supplementary cementing materials. A two level fractional design has been implemented to study the effect of 15 variables and assess their effect on the durability of cooling tower fill. Initial results are encouraging.

(b) Report:

- CANMET 85-7E

(c) Contracts:

- Reqn. 2-9200 "The utilization of Canadian pozzolanic materials to counter alkali-aggregate reaction in concrete", Canada Cement Lafarge. S.A. J.A. Soles. "Modification of existing creep jigs at Univeristy of Calgary", Canada Cement Lafarge. S.A. - G.G. Carette.

- Reqn. 3-9227 "Blast furnace slag granulation", W.M. Watts Engineering Ltd. S.A. - E. Douglas. "Characterization and performance in concrete", Watts Engineering Ltd. S.A. - V.M. Malhotra/ E. Douglas.

- Reqn. 4-9037 "Energy conservation by chemical comminution of asbestos - phase II", Ontario Research Foundation. S.A. - D.M. Doyle.

- Reqn. 4-9156 "To develop an asbestos cement (A/C) cooling tower fill for thermal generating plants", Atlas Turner Inc. S.A. - E. Douglas.

- Reqn. 4-9174 "Characterization of granulated blast furnace slag for portland cement replacement in concrete", Ontario Research Foundation. S.A. E. Douglas.

- Reqn. 4-9236 MDA "A study of the alkali aggregate reactivity of potential concrete aggregates", ADI Limited. S.A. - J.A. Soles.

- Reqn. 4-9308 MDA "Development of engineering data on N.S. fly ashes", L.E. Snow Limited. S.A. - G.G. Carette.

- Reqn. 4-9315 "Evaluation of waste crushed rock for US in concrete rail road ties", Lamarche McGuinty Inc. S.A. - J.A. Soles.

- Reqn. 4-9334 "Review on national pozzolans for use in concrete", P.K. Menta. S.A. - M. Malhotra.

- Reqn. 5-9185 "State-of-the-art review on D-crashing of concrete in Manitoba", Hardy Associates Ltd. S.A. - E. Douglas.

- Reqn. 5-9252 "Hardware and software modifications for the conduction calorimeter system", Third Wave Engineering. S.A. - E. Douglas.

• **Project 30.37.02:** ERD - Concrete for Offshore Structures
Project leader : V.M. Malhotra

Objective:

To develop engineering data on high strength, low permeability, and high impact resistance concrete and grouts for offshore structures; to develop concrete permeability and ice abrasion resistance and NDT monitoring inspection tests.

Oil exploration and production activities in the off-shore arctic environment are expected to increase in the near future. It is anticipated that many of the offshore structures will be constructed of concrete. At present there are many unknown factors related to the performance of concrete structures in the arctic environment. The extreme cold adversely influences the properties of concrete. The ice creates additional problems of abrasion and impact. It is therefore essential that studies be performed to develop concretes which will be durable in the arctic environment. Such concrete should have high strength, low permeability and low unit weight. Also, testing methodology should be developed to determine abrasion resistance and permeability of these special concretes.

(a) High-strength lightweight concrete

In-house work on the development of high-strength light-weight superplasticized concrete was continued. In this phase of the program, the effect of the incorporation of steel fibres was investigated. Initial studies indicate that satfactory workable concrete can be made using steel fibres with moderate aspect ratio, and the fibres contribute considerably to the impact resistance of concrete.

(b) The 7th yearly inspection of test prisms installed at Treat Island, Maine was performed.

Visual checks were made and photographs taken. A display and a report is prepared for presentation at the 2nd International Conference on the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, to be held in April, in Madrid, Spain.

(c) Contracts:

- Reqn. 4-9019 "Yearly inspection of fly ash/slag concrete test specimens exposed at Treat Island", University of New Brunswick, completed. S.A. G.G. Carette.

- Reqn. 4-9041 "Reproducibility of a new technique to measure the permeability of concrete", Laboratoire de Bréton Ltée. S.A. - G.G. Carette.

- Reqn. 4-9171 "Low-permeability high-strength fibre-reinforced normal weight concrete for offshore structures", Canada Cement Lafarge. S.A. - G.G. Carette.

- Reqn. 4-9173 "Development of a test to determine the resistance of concrete to abrasion and impact by ice under offshore arctic conditions", Arctec Canada Ltd. S.A. - V.M. Malhotra.

- Reqn. 4-9212 "Development of cementitious grouts for post-tensioned concrete members for use in offshore structures in the Arctic environment", B.H. Levelton and Assoc. Ltd. S.A. - H.S. Wilson.

- Reqn. 4-9246 "Evaluation of the suitability of existing repair materials to deal with potential types of damage", Ontario Hydro. S.A. - H.S. Wilson.

- Reqn. 4-9249 "Development of portable test equipment employing pulse-echo techniques to determine flaws in concrete", Techno Scientific Inc. S.A. - V.M. Malhotra.

Biotechnology

- **Project 30.45.01:** Bioleaching
  Project leader : R.G.L. McCready

Objective:

To utilize microorganisms in extraction and beneficiation processes to exploit mineral deposits which cannot be treated economically by normal processing.

(a) Bacterial leaching of sulphide ores

The objective is to develop an economically viable biohydrometallurgical process to extract and recover secondary metal values from sulphide ores, specifically those portions of mineral deposits which are left underground for mine support or which are below cut-off grade for conventional mining.

Typically 30% of mineral deposits are left untouched in most mining operations. Treatment of such residual resources by bacterial leaching would enable complete utilization of ore reserves.

Column leaching studies on a Noranda and a Falconbridge copper ore have indicated an average copper extraction rate of about 1% per month using bacterially-assisted leaching with ferric sulphate at pH 1.5. The rate determining factor appears to be the diffusion rate of the lixiviant into the ore particles.

(b) Removal of silica from alumina ores (bauxite, clays, etc.) by biohydrometallurgical methods

The objective is to develop a biohydrometallurgical process to upgrade alumina ores by the solubilization and removal of silica. In the short term, the aim is to upgrade bauxite by reducing the level of silica which interferes with the production of alumina by the Bayer Process. The long term objective is the utilization of Canadian alumina resources as feed for aluminum processors.

A literature review has been completed and preliminary studies utilizing microorganisms isolated from bauxite samples did not solubilize silica. Studies are being initiated to test various microbially produced organic acids and metabolites as silica solubilizing agents. Once such an agent is found various microorganisms known to produce the metabolite will be tested on bauxite ores for their silica solubilizing ability.

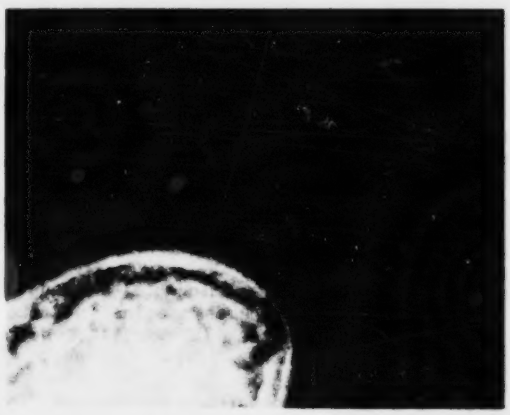

Fig. 5. An electron micrograph of Thiobacillus ferrooxidans showing the flagella and fimbriae

• **Project 30.45.02:** Biological Impact on Unit Operations
Project leader : R.G.L. McCready

Objective:

To identify, quantify and apply biological phenomena which enhance performance of unit operations used in the Mineral Processing and Mineral Resource Extraction Industries.

The various projects were supported by contract funds from the National Biotechnology Strategy.

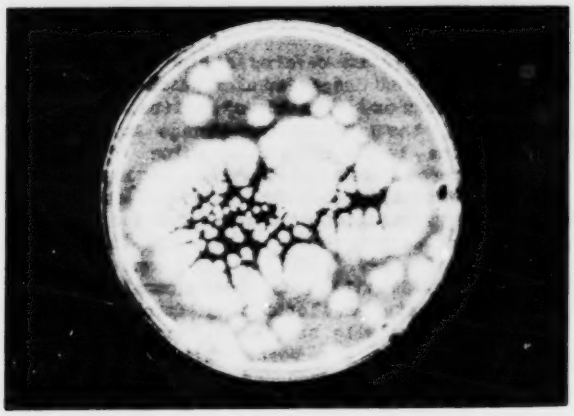

Fig. 6. An agar plate of an acidophillic Penicillium isolated from a uranium leaching stope which adsorbs uranium onto its cell walls

(a) Report:

-MRP/MSL 85-154 (J)

(b) Contracts:

- Reqn. 5-9042 "Technical and economic comparison of uranium recovery from bioleach solutions by the use of biomass, ion-exchange and reverse osmosis", Mellis Consulting Engineers. S.A. - V. Sanmugasunderam.

- Reqn. 5-9156 "Microbial control of tailings dump leaching", Department of Biology, The University of Ottawa. S.A. - G.M. Ritcey.

- Reqn. 5-9160 "Study on microbial degradation/alteration of carbonaceous species in Canadian ores and concentrates (UP-W-259)", Witteck Development Inc. S.A. - R.G.L. McCready.

- Reqn. 5-9166 "Biological control of Thiobacillus ferrooxidans by predatory organisms", Ontario Research Foundation. S.A. - R.G.L. McCready.

- Reqn. 5-9180 "Literature review to determine the potential for genetic engineering of T. ferrooxidans", Lynton S. Gormely. S.A. - R.G.L. McCready.

- Reqn. 5-9181 "Bioadsorption capacity of Denison Mines Biomass isolates", Acres, Davy McKee Engineering Inc. S.A. - V. Sanmugasunderam.

- Reqn. 5-9236 "Acidophillic aquatic mosses as biological polishing agents", Boojum Research Ltd. S.A. - R.G.L. McCready.

- Reqn. 5-9247 "To compare the biological reactivity of mineral ash of New Brunswick coal to that of Cape Breton coal", The Atlantic Coal Institute. S.A. - R.G.L. McCready.

• **Project 30.45.03:** Biotechnology Networking
Project leader : R.G.L. McCready

Objective:

On a continuing basis to maintain and expand a network to improve the interaction and communication between the research community and Canadian Industry, and to improve the availability and accessibility of relevant information.

- Prepared and published three BIOMINET (Mineral Leaching and Metal Recovery Network) Newsletters to keep members aware of current research projects and developments in the application of biotechnology in the mineral industry.

- Participated in two biotechnology training courses for NRC Technical Advisors at the University of Waterloo.

- Participated in the biotechnology seminar sponsored by Falconbridge Nickel at Cambrian College in Sudbury.

- Organized the annual meeting of BIOMINET, which was attended by 87 members at the Sheridan Park Conference Centre, Mississauga, Ontario.

- BIOMINET Database: Two major modifications were made to the BIOMINET survey.

(a) Reports:

- MRP/MSL 85-27 (TR)
- MRP/MSL 85-150 (OP)
- MRP/MSL 85-156 (OP)

Extraction - Metallic

- **Project 30.52.02:** Chloride Processes for Sulphide Ore Treatment
  Project leader : B.H. Lucas

Objective:

To develop and evaluate viable chloride metallurgical processes which will achieve the goals of metal recoveries above 90% and the elimination of SO_2 emissions by yielding elemental sulphur or stable sulphides from bulk sulphide concentrates.

Although New Brunswick has the largest reserves of zinc, lead and silver in Canada, the complexity of these sulphide orebodies has resulted in inefficient recovery of high value saleable products using existing technology. In order to improve metal extraction efficiency it is necessary to produce a bulk concentrate. However, because of its complexity and relatively low grade, this bulk concentrate is not amenable to conventional smelting. CANMET has been investigating and evaluating chloride processes for the treatment of these complex concentrates. In-house work has largely confirmed the basic flowsheet. Current activities relate mainly to the complete technical assessment and demonstration of process alternatives on New Brunswick and similar complex sulphide ores. Such processes are viewed to be beneficial in that they provide significantly higher metal recoveries.

Smelting processes for sulphide ores produce SO_2 most of which is presently emitted to atmosphere. Increasing concern over "acid rain" will result in the enforcement of more stringent environmental regulations on SO_2 emissions. Although reductions in SO_2 emissions can be achieved by conversion to sulphuric acid in an acid plant, marketing constraints on the acid make alternate long term solutions desirable. Processes which produce elemental sulphur instead of SO_2 are potentially viable alternatives. Chloride technology offers such a process, but must be well demonstrated prior to industrial acceptance.

(a) Ferric chloride leach process

The Phase II contract was completed along with two semi-continuous pilot plants at CANMET. The FCL process parameters were confirmed and the process subjected to an economic assessment. It was found that the FCL process was more capital-intensive than the Sherritt Gordon PSA process but less than the RPC-SRL process.

(i) Purification of Chloride Leach Solutions

The cementation of Bi, Cd, Co, Cu, Pb and Ni from various chloride solutions using zinc dust has been studied. In HCl solution, the rate of removal of these impurities was in the order Cu> Pb>Cd>Bi>>Ni>Co. One hundred percent of the combined impurities was cemented from a 0.2 M HCl + 2.0 M NaCl + 50 g/L $ZnCl_2$ solution after 4 minutes. This solution is suitable for Zn recovery by electrowinning.

(ii) Silver in Chloride Solutions

The cementation kinetics of silver on copper and lead metal in brines were studied. The behavior of silver metal towards ferric ion in the absence of chloride was studied to compare the results to the chloride medium. Current work focusses on silver impurity in particulate copper during electrowinning from aqueous chloride media.

(iii) Solubility of $PbCl_2$

The results of lead chloride solubility studies have been summarized and are the basis for a more detailed fundamental study. In relatively low-iron containing media (<0.3 M), the lead solubility seems to be a complex function of the temperature, total chloride concentration, and the type of co-electrolytes present. This may be related to the extent of dissociation of the co-electrolytes and to the stabilizing influence of various cations on the anionic lead-chloro complexes: $Na^+ > Mg^{2+} > Fe^{2+}$, $H > Fe^{3+}$.

The measurements are also being extended to more concentrated iron chloride media of direct interest to CANMET's Hydrometallurgical Lead Process. In the absence of stabilizing NaCl additions, ionic saturation effects were observed, which limit the overall lead solubility. Ferric chloride, especially, appears to compete with lead for free ligands, whereas ferrous chloride continues to donate free chloride up to fairly concentrated levels.

(iv) Purification and regeneration of leaching solutions

Preliminary kinetic measurements on the chlorination of ferrous chloride leach solutions confirmed that the reaction is gas film controlled. Some fundamental relationships were extracted to improve the reactor design procedure. More accurate measurements are scheduled, involving the installation and use of process control equipment, especially assembled for this purpose.

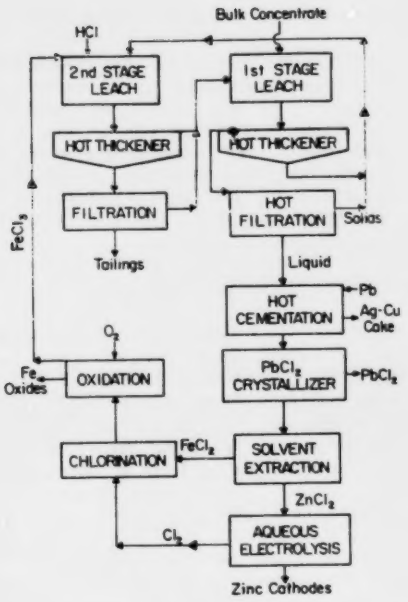

Fig. 7. Proposed two-stage ferric chloride leach process flowsheet

An alternative iron removal option by means of oxygenation of regenerated leach solutions was investigated. Results indicated that process criteria are met by rejection of up to 5 g/L iron in form of well filterable akageneite, at pH <1 and 90°C.

(v) Zinc Solvent Extraction

In conjunction with the pilot plant campaign tests were carried out to study the extraction of zinc from the ferric chloride leach liquors. The study, using TBP, has determined the number of stages required for extraction, scrubbing of impurities and stripping. To clean up the impurities in the strip liquor, a scheme has been developed which consists of treatment of a bleed stream of the strip liquor with zinc oxide to precipitate ferric hydroxide, followed by passing through activated carbon to remove trace organics. This solution is treated with zinc dust to cement out the last of the metallic impurities such as copper and cadmium and is then sent to electrowinning after an adjustment of the acid level.

(vi) Electrolytic Lead Recovery

Attempts to electrowin long-term, smooth, compact, dendrite-free lead deposits from aqueous chloride electrolyte were not successful. Consequently, attention was focussed on electrowinning uniform metallic lead crystals that could be removed continuously from the cell. During this review period, a laboratory diaphragm cell featuring a cathode compartment with a tapered bottom was developed and experimental conditions were established for electrowinning loose, uniform, leaf-like crystals of 99.98% pure lead from aqueous chloride electrolyte.

(vii) Copper Electrowinning from Chloride Electrolyte

The effect of various organic additives on the structural characteristics of copper deposits electrowon at 161 A/m² from aqueous chloride electrolyte using a diaphragm cell featuring electrolyte agitation by vibrating the cathode has been evaluated and reported. Current experimental work is directed towards developing an electrolysis process whereby coarse, uniform copper crystals are continuously removed from the cell. The study also includes an evaluation of the effect of various impurities, Fe, Pb, Ni, Ag, As and Sb on the purity of the electrowon copper.

(vii) Zinc Electrowinning from Aqueous Chloride Electrolyte

Conditions have been established for electrowinning smooth, compact, dendrite-free zinc deposits from acid zinc chloride electrolyte using a diaphragm cell featuring catholyte agitation by air sparging both at the bench and semi-pilot level. During the current review period, a full-height cell was used to verify that quality zinc deposits could be electrowon from actual electrolyte produced by the ferric chloride leach (FCL) process.

(b) Galena leaching

Work on the leaching of galena in ferric chloride media has been completed, and the final report was prepared. Galena dissolves rapidly under all conditions, and the rate is controlled by the outward diffusion of the $PbCl_2$ reaction product through the constantly thickening layer of the elemental sulphur reaction product. As a general observation, any parameter which affect the solubility of $PbCl_2$ also affects the rate of leaching.

(c) Leaching of silver minerals

The ferric chloride leaching of silver, and antimonian silver and silver chloride were studied over the temperature range 40-95°C and for a wide range of solution compositions. Rapid leaching rates together with linear kinetics were observed under all conditions. The rate is diffusion controlled, and is strongly affected by solution composition, generally increasing with chloride concentration and decreasing with AgCl concentrations. Although the study was fundamental in nature, it has the practical ramification of suggesting that the dissolution of these silver minerals will create few problems in any ferric chloride leaching process.

(d) Reports:

- MRP/MSL 84-7 (TR)
- MRP/MSL 85-14 (J)
- MRP/MSL 85-29 (TR)
- MRP/MSL 85-46 (TR)

- MRP/MSL 85-69 (OP)
- MRP/MSL 85-136 (TR)
- MRP/MSL 85-137 (TR)

(e) Contracts:

- Reqn. 3-9050 "Viscosity measurements and technical evaluation of melts in the $PbCl_2$-NaCl-KCl and $PbCl_2$-KCl-LiCl systems", University of Toronto. S.A. - Dr. K.G. Tan.

- Reqn. 4-9177 "Assessment of methods for dry-way chlorination of sulphide ores", Jan H. Reimers & Assoc. Ltd., completed. S.A. - G.M. Ritcey.

- Reqn. 4-9202 MDA "Optimization of the CANMET $FeCl_3$ leach process", Bacon, Donaldson & Assoc., completed. S.A. - B.H. Lucas.

- Reqn. 4-9209 MDA "Bench scale evaluation the application of the Great Central Mines hydro-metallurgical copper process to Hudson Bay Mining and Smelting", Hudson Bay Mining and Smelting Co. Ltd. S.A. - W. Craigen.

- Reqn. 5-9174 "Lead chloride electrolysis: New technology appraisal and conceptual design of a cell", SNC Inc. S.A. - J.E. Dutrizac.

- **Project 30.52.03:** Gold
  Project leader : G.M. Ritcey

Objective:

To develop new or improved processes to increase the recovery and reduce costs in the extraction of gold and associated precious metals.

In many gold deposits such as low grade, refractory, placer deposits, etc., the complexity of the orebodies and low concentrations have seriously limited their exploitability. Low concentration is also the reason for which many gold tailings are not fully exploited. Environmental concern over the arsenic oxide emissions caused by roasting of arsenical ores is another problem which needs a solution. The cyanidation is not always effective since it is very difficult to extract gold by simple cyanidation from these refractory ores. It is therefore important for CANMET to develop a strong background and find ways to increase and improve gold extraction from the above mentioned types of ores avoiding also serious environmental damage caused by CN^- effluent and arsenic oxide emissions.

(a) Development of a new ultra-sensitive micro-analytical technique for in-situ analysis of minerals was explored with Dr. S. Chryssonlis (RPC). Gold was successfully implanted in a number of specially selected sulphide minerals and preliminary tests were done at Surface Science Western with their ion microprobe. The implanted gold profile was determined in an arsenopyrite but further tests were not possible due to gold contamination in the ion microprobe. Future tests are planned after removal of the contamination.

(b) Electronic sorting and gold ores

Testwork is continuing by Aggen Inc., Peterborough, to study the possibility of upgrading gold resources (active mines and waste dumps) by electronic sorting. The program consisted of identifying a representative number of past and active gold mines, samples procurement and carrying out tests for electronic sortability by photometric and/or conductivity trials.

The results of the testwork performed by Aggen Inc. indicated that many gold resources in Ontario were amenable to electronic sorting.

A CANMET representative was assigned, following the request of the Ontario Ministry of Natural Resources, to act as technical adviser for this testwork program.

(c) The Knelson Concentrator, a newly developed centrifugal separator for gold and other heavy minerals was examined in batch and commercial size operation. The equipment seemed to offer good potential for recovery of liberated heavy minerals.

(d) As an alternative lixiviant to cyanide, a number of other reagents have been investigated for possible application to conventional and refractory gold ores. These include thiourea and chloride.

Thiourea leaching studies have been concerned with the optimization of the leaching efficiency while minimizing the degradation of thiourea. The leaching appears to be controllable and optimization tests are continuing. Greater than 90% recovery of gold resulted at a pulp density of 30% solids. Subsequent purification studies on the leach solution have commenced in which cementation, carbon adsorption, ion exchange and solvent extraction are being evaluated as to technical and economic viability.

(e) Work continued on the development and optimization of a solvent extraction separation flowsheet for the stagewise recovery of Au, Pt, Pd from chloride solutions. A pilot plant was carried out at the Royal Canadian Mint and was essentially successful, with some further optimization being required.

(f) Analytical development

(i) Determination of thiourea in gold leach solutions

A titrimetric method involving oxidation with potassium dichromate and back-titration with ferrous ammonium sulphate has been applied to the determination of free thiourea in gold leach solutions. Results obtained were in relatively good agreement with spectrophotometric results obtained by measurement of free thiourea in the ultraviolet region of the spectrum.

(g) Gold recovery from the refractory ore or concentrate invariably involves a pretreatment process before cyanidation. Presently, arsenopyritic gold ore concentrates from Campbell Red Lake Mines are under active investigation with various types of hydrometallurgical pretreatment processes (e.g. oxidative acid or alkali leaching at ambient pressure as well as under oxygen pressure, $FeCl_3$ or Cl_2-H_2O leaching or microwave irradiation).

Apart from pretreatment direct gold leaching, thiourea, chlorine leaching from the refractory ore or concentrate is also under investigation. A thorough literature search on the pretreatment processes of refractory gold ores has been completed.

(h) Contracts:

- Reqn. 4-9180 "Investigation of adaptability of the Knelson Concentrator to ore beneficiation", Lee-Mar Industries Ltd. S.A. - M.A. Cristovici.

- Reqn. 4-9217 "Direct recovery of gold precious metals from loaded organics with hydrogen", McGill University. S.A. - G.M. Ritcey.

- Reqn. 5-9026 "Recovery of gold by single-stage deep-fluidized bed, ion exchange and carbon techniques", Ontario Research Foundation. S.A. - G.M. Ritcey.

- Reqn. 5-9052 "Direct recovery of gold/precious metals from loaded organics with hydrogen", McGill University. S.A. - G. Pouskouleli.

- Reqn. 5-9063 "Randal report - phase III", Randal International Ltd. S.A. - G.M. Ritcey.

- Reqn. 5-9073 "Development of rotary leach vessel technology for the recovery of gold and silver by cyanidation", Hatch Associates Ltd. S.A. - E.G. Joe.

- Reqn. 5-9093 "Evaluation of resin-in-pulp technology for Canadian gold ores", Witteck Development. S.A. - G.M. Ritcey.

- Reqn. 5-9098 MDA "Development of R&D project descriptions for gold and metallic minerals processing in N.S.", P. Maltby, completed. S.A. - M. Stefanski.

• **Project 30.52.04:** Plasma
Project leader : J.M. Skeaff

Objective:

To investigate and develop applications of plasma technology in the fields of energy utilization and pyrometallurgy as a means of increasing energy use efficiencies and of substituting electricity for fossil fuels.

It is becoming increasingly evident that plasma technology has the potential in many instances for the efficient substitution of electrical energy for fossil fuels utilization as well as for completely new applications. It is also evident that plasma technology has developed to the state where applications on an industrial scale are being seriously considered, are planned or are a reality. However, Canada, although possessing more than adequate supplies of relatively inexpensive electricity, lags behind the development of industrial plasma technology. To assist in the development of these applications, CANMET has accepted the lead agency role in the field within the federal government.

(a) Plasma technology in metallurgy

Meetings and discussions have been conducted with research and industrial organizations interested in developing or employing plasma technology in areas such as direct smelting of iron ore, vanadium production and drying processes. Studies have been funded to identify the technical and economic potential for plasma technology applications in Canada.

Field trips were made to research institutions and industrial installations with thermal plasma facilities to follow up recent developments and to gain knowledge of this growing technology. A visit to Voest Alpine, Austria, the largest operating plasma facility in the world, was made and discussions with technical personnel were conducted leading to the acquisition of valuable information about the industrial application of plasma technology.

CANMET's small-scale 100 kVA plasma reactor, which is presently being installed, is designed to investigate the production of ferro-alloys, high quality stainless steels and superalloys in a single stage, rather than the conventional multistage processes currently in use.

(b) Plasma technology in fossil fuels processing

An unsolicited proposal was funded to investigate the production of petrochemical feedstocks by the

hydropyrolysis of tar sands coke in a plasma-fired spouted-bed reactor. Final results indicate that acetylene and ethlylene are produced in the reactor, but at such low concentrations as to make the process impractical.

(c) Contracts:

- Reqn. 3-9043 "Petroleum coke gasification in a plasma jet reactor", M. Boulos, University of Sherbrooke. S.A. J.M. Skeaff.

- Reqn. 4-9010 "A survey of the potential for, and the development of, a strategy for plasma technology applications in Canada", SNC Ltd., Montreal. S.A. J.M. Skeaff.

- **Project 30.52.05:** Impurities in Copper Refining
  Project leader : J.E. Dutrizac

Objective:

In co-operation with the Canadian copper industry, to develop, by 1990, improved technologies for the characterization, deposition, control and processing of impurities in electrolytic copper refining.

Canada is a major producer of primary copper for both domestic and export requirements, and virtually all the nation's primary copper is produced by smelting. During smelting, many of the impurities contained in the copper concentrates are collected in the blister copper smelter product. It is necessary to remove such impurity elements from the blister copper both to meet market requirements for copper conductivity and to recuperate valuable byproducts. Electrorefining in a $CuSO_4$-H_2SO_4 electrolyte is universally used for this purification. The issue of impurity containment is of concern to all producers as it impacts directly on tankhouse operation and the profitability of the entire plant. Most of the Ag, Au, Se and Te form insoluble products (anode slimes) during electrorefining. Although anode slimes processing has been carried out for many years, much remains unknown or unsure about this process, and the problems associated with anode slimes are expected to intensify. If the Canadian smelting industry is to remain viable in the face of depressed copper prices and keen international competition, technological responses must be developed to overcome current problems.

(a) Mineralogical studies

Copper anodes have been obtained from the four Canadian copper producers. Preliminary metallographic studies have been performed, and it is planned to carry out detailed investigations to ascertain how the troublesome impurity elements occur in the blister copper. The detection limit of solid solution impurities will be extended by the use of micro-PIXIE techniques.

Several mineralogical studies of the anode slimes formed during commercial electrolysis have been done. The slimes are extremely complex and fine grained. It has been shown that the slimes mineralogy depends greatly on the Ag:Se ratio in the blister copper. An experimental program was carried out to examine the deleading of anode slimes using ammonium acetate, acetic acid or brine. The ammonium acetate approach was favoured, and the preferred conditions for the deleading operation were defined.

(b) Anode passivation

Anode passivation effects are of major industrial concern. In support of this industrial interest, several foreign language papers were translated, and the translations were distributed to the industry. Support was given to a cooperative research proposal to study anode passivation at Laval University, and such fundamental studies will be of long-term benefit to the project. Passivation studies will also be carried out at CANMET, and Fig. 7 shows some small pilot scale refining cells which will be used to assess the polarization behaviour.

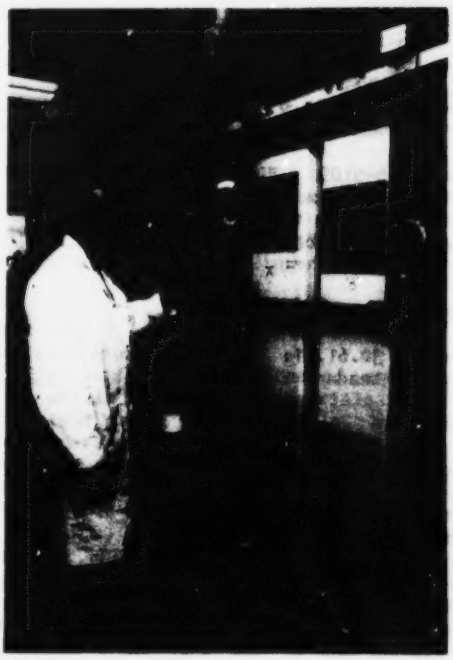

Fig. 8. Small pilot scale copper refining cells for the study of anode polarization

(c) Arsenic in copper refining

Arsenic is a difficult element to control in copper refining, and it creates hygiene problems in the copper liberator circuits. Analytical methods were developed for the analysis of As(III) and As(V) in copper refining solutions

using ion chromatography. In one procedure, As(V) was determined by conductivity detection, and As(III) was likewise analyzed after oxidation with aqua regia. In the second procedure, As(III) was determined with an electrochemical detector while As(V) was analyzed simultaneously by conductivity detection. The analytical procedures developed have been used to analyze As(III) and As(V) in solutions from operating refineries.

Efforts are being made to produce arsenical copper to be used in the industry for anode doping as a means of polarization/slimes control. The objective is to investigate the feasibility of producing copper arsenide cathodes using arsenic-doped copper liberator electrolyte. A literature review has been completed and some preliminary experimental work has begun.

(d) Alternate technologies

To ascertain the potential of chemical refining processes, a literature review on the use of organic leaching agents for copper purification was carried out and a report was issued.

(e) Reports:

- MRP/MSL 85-21 (J)
- MRP/MSL 85-56 (TR)
- MRP/MSL 85-120 (LS)

(f) Contract:

- "Reqn. 5-9109 "Development of an improved method for monitoring the composition of electrolyte in the copper refinery", INCO Ltd. S.A. - D.J. MacKinnon.

Extraction - Radioactive

- **Project 30.61.01:** Uranium Process Development
  Project leader : G.M. Ritcey

Objective:

To effect significant improvements in uranium processes with respect to recovery of by-products, process efficiency, economics and environment impact.

Canadian uranium is a well-established and prosperous industry. However, as new ores are discovered and as environmental concerns increase, the limitations of the well known conventional sulphuric acid leaching process become more evident. At CANMET, a systematic review of the existing process has identified many areas for improvement such as efficiency of oxygen use, ion exchange and solvent extraction practice, precipitation inefficiencies, and most particularly environmental limitations posed by radium, arsenic, nickel, etc. CANMET has taken two approaches: (i) improvements in conventional sulphuric acid practice; and (ii) a more radical new technology using chloride metallurgy. Interestingly, benefits may be converging into an entirely new flowsheet incorporating the strong points of both approaches. The benefits could well play a significant role in future uranium plants.

Extraction and Purification

(a) Pressure leaching of low grade and complex ores continued, both in-house research and under a small contract. This is the process whereby the ore is slurried in water (and acid if insufficient pyrite is present). $CaCl_2$ added to solubilize the radionuclides has proven successful on both low grade ores of Elliot Lake and the complex and higher grade ores of Key Lake. Recoveries have been typically 95% U with a final residue of 35 pCi/g ^{226}Ra for Elliot Lake ores, and 99.6% U recovery with a final residue of 60 pCi/g ^{226}Ra.

(b) Limited work continued on the recovery of rare earths from process effluents, and the technology appears to be leading at present to the possible application to an industrial property. The work will be started under a cost-recovery contract at CANMET during 1986/87 period.

(c) Investigations continued on the possible development of a new stripping sequence that would not only permit the recycling of reagents, but would also provide a high purity produced at the mill. The product is a fluoride (which could be subsequently converted to other materials). A continuous circuit has been run and the products and streams are presently being analysed.

(d) Adsorption of ^{226}Ra from uranium tailings seepage water

Three potentially applicable methods are being investigated. They are:

i) ion exchange, utilizing DOWEX XFS radium-specific resin;

ii) barite fluidized-solid contactor, utilizing finely ground natural barium sulphate;

iii) bioadsorption, which involves a nutrient-enhanced bacterial colony which is indigenous to uranium tailings. Contactors are of two types, one a column filled with crushed silica or apatite rock, the alternative a rotating biological contactor involving extensive plastic surfaces.

All three methods have proven to be effective in lowering the ^{226}Ra concentration of the final effluent to <10 pCi/h from an influent range of 80-160 pCi/L. Ion exchange and barite have achieved an effluent of <4 pCi/L over long periods of throughput. Throughout this experimentation the feed solution has been obtained from related lysimeter studies.

Bacterial populations, initially at ~3 x 10^5 cells/mL in the lysimeter effluent, were enlarged 10 fold in the bioreactor liquid medium. The cell count in the clarified effluent (flocculated and filtered) was the order of 3 x 10^5 cells/mL. Undiluted bioreactor sludge loadings were the order of 1000 pCi ^{226}Ra per gram of dry solids.

The indigenous bacteria were isolated and identified as Proteus mirabilis and Pseudomonas fluorscens. In the operation of ion exchange columns bacteria multiplied considerably, thus interfering with the system in several respects.

(e) Infrared studies on cruds

Using infrared spectroscopy, an investigation of cruds and solutions from circuits for the solvent extraction of uranium and of cobalt was made to determine the presence of materials possibly contributing to crud formation. Because of their tarry character freeze grinding was required to prepare the cruds for infrared analysis. Hexane and carbon tetrachloride extracts of these cruds and the resulting residues were examined. Superimposed spectra of inorganic materials and/or organic reagents prevented identification of minor components. Because some of the organic solutions reacted with matched kBr cells these could not be used. Instead disposable AgCl cells were used; these gave acceptable spectra despite a slight reaction with amine present in the solutions. Weak broad absorption in the carbonyl absorption region indicated the possible presence of minor amounts of oxidation products. Isolation of these products by absorption on various absorbing materials were hampered by the highly polar reagents present and results of attempts to identify them were not conclusive.

(f) Analytical development

(i) Analysis of acid leachates and solvent extracts from uranium processing

Aluminum, arsenic, calcium, iron, magnesium, molybdenum, sodium, nickel, silicon, vanadium and zirconium were determined directly, without prior separation of uranium, in a series of acid leachates and solvent extracts by atomic-absorption spectrophotometry and X-ray fluorescence. They were also determined indirectly by inductively-coupled plasma-atomic-emission spectroscopy after separation by uranium by tri-n-butyl phosphate extraction as the nitrate. The results obtained by the three methods were in reasonably good agreement.

(g) Feasibility of acid chloride leaching of Midwest Lake uranium ore (a typical high grade complex ore) was studied with several leachates (e.g., HCl, Cl_2-H_2O, HCl-O_2 press., HCl-$CaCl_2$-O_2 press., HCl-$CaCl_2$ and $FeCl_3$). Irrespective of leachates uranium extractions were always high (>99%). Aqueous chlorine (Cl_2-H_2O) leaching was not effective for radium extraction. Ferric chloride leaching was effective for radium extraction but not for arsenic extraction.

Furthermore, two stage HCl leaching, 4-stage counter-current HCl leaching and HCl-$CaCl_2$-O_2 pressure leaching provided high extractions for U, Ni, As and Ra. Residues contained 315 pCi/g, 215 pCi/g and 178 pCi/g radium respectively.

(h) In the development of an alternative leaching process for the uranium ore an entirely new approach has been undertaken. This new approach involves first selective KCl leaching of radium from the uranium ore and then uranium and other metal values (e.g., Th, Ni or As) by acid leaching of this radium preleached ore. In fact 60-65% radium was selectively leached from Midwest Lake uranium ore with 2M KCl at 50°C and U >99%, Ni 88%, As 90% and Ra 96% extraction from this Ra preleached ore by HCl leaching (88.0 kg HCl/tonne, 70°C, 4 h, 50% solids). Radium level in the final leach residue was only 108 pCi/g solids.

(i) Contract:

- Reqn. 4-9067 "Controlled oxidation leaching technique for arseniferous uranium and other ores", McGill University. S.A. G.M. Ritcey.

Pressure oxidation leaching has been shown effective for the complex ore of Saskatchewan as well as other arseniferous ores.

Standards and Specifications

- **Project 30.69.01:** Reference Materials
  Project leader : H.F. Steger (C.W. Smith, Acting)

Objective:

To prepare and certify samples of ores, concentrates, metals and related materials for use as compositional reference materials, by means of interlaboratory and in-house programs. The compilation of methodological information from these programs is an important ancillary benefit to CANMET and the analytical community. In 1985/86, The Canadian Certified Reference Materials Project (CCRMP) distributed approximately 1350 units of reference materials to users in Canada and abroad generating a revenue of approximately $105,000.

CCRMP strives to fulfill the demand from Canadian industrial, commercial and research laboratories for geological materials. CANMET through CCRMP offers both the expertise and facilities and the continuity and impartiality that are essential for long-term credibility and public acceptance of reference materials. Most industrialized nations have similarly assigned the production of reference materials to government institutions.

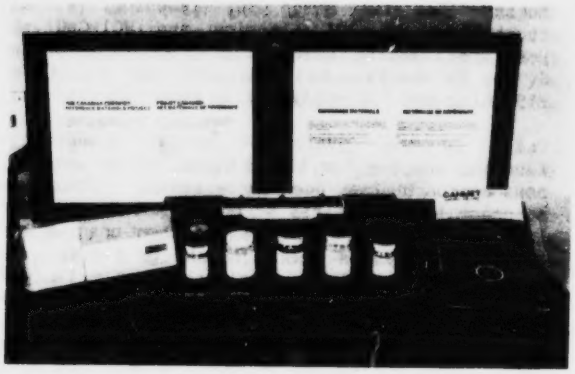

Fig. 9. Some sixty different CCRMP materials are currently available to a world-wide clientelle in mineralogical, metallurgical and earth-science realted industries

(a) Current state of reference materials

In this period, industrial, government and commercial laboratories continued to contribute analytical results of the interlaboratory certification programs. The analyses of the Chemical Laboratory provided results for the confirmation of the homogeneity, the certification program and for the total chemical composition.

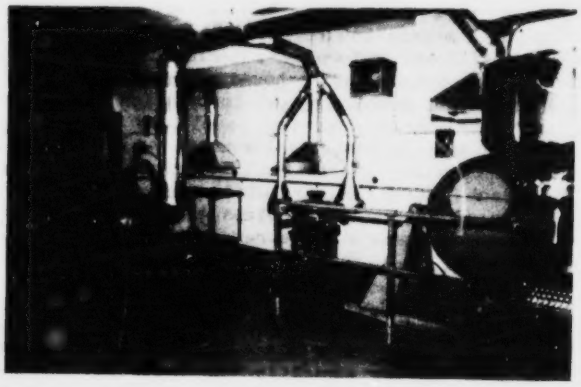

Fig.10. A high efficiency self-contained dust extractor was recently installed in the CCRMP sample preparative facility

Uranium ore RL-1 and gold ore MA-1a were certified and offered for sale. The interlaboratory program to certify gold in ores MA-2a and MA-3 was completed.

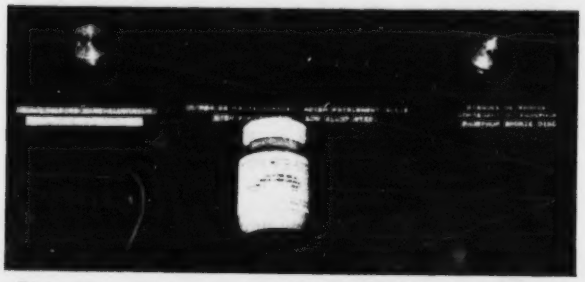

Fig. 11. Gold ores led sales of CCRMP certified reference material in the past year

An interlaboratory measurement program to determine recommended values for individual lanthanides, uranium, thorium and potassium in brithollite ore OKA-2 was completed. The preparation of RGTh-1, a thorium series gamma-ray spectrometry calibration material to be prepared by silica dilution of OKA-2 on behalf of The International Atomic Energy Agency, has been deferred pending completion of arrangements.

Assessment of interlaboratory measurement data to determine recommended values for seven elements in zinc-aluminum reference alloys NZA-1 to NZA-7 is approaching completion. An emission spectrometry measurement program to establish the disc-form homogeneity parameters has been recently completed.

Additionally, CCRMP contributed preparative facilities and expertise for several reference materials projects of external agencies:

Vegetative reference materials CLV-1 and CLV-2 were sterilized by gamma irradiation at facilities of Atomic Energy Canada Ltd. on behalf of the National Uranium Tailings Research Program.

Six non-metallic electrolytic bath reference materials were prepared on behalf of Alcan International Limited, Arvida Laboratories.

Ten gold-bearing till samples for exploration sampling/analysis research were blended on behalf of the Department of Geological Sciences, Queen's University, Kingston.

Lake and river sediment samples were comminuted and blended on behalf of the Resource Geophysics and Geochemistry Division, Geological Survey of Canada.

Mineral Sciences Laboratories contributions to the characterization of thermal transport reference materials in an international measurement project were deferred pending the repair of essential equipment.

(b) ISO/REMCO (Reference Materials)

This ISO Council Committee is responsible for the development of ISO Guides on all aspects of reference materials to be used by all ISO technical committees. Two MSL officers serve on this committee, one of them serves as convener of the joint working group between ISO/REMCO and ISO/TC 69, responsible for statistical aspects of reference materials. The work during the review period has been the development of ISO Guide 33 on the uses of reference materials for assessment of measurement procedures.

(c) Reports:

- CANMET 84-11
- CANMET 84-14
- CANMET 85-1
- CANMET 85-4
- MRP/MSL 84-46 (J)
- MRP/MSL 84-69 (J)
- MRP/MSL 84-98 (J)
- MRP/MSL 84-142 (J)
- MRP/MSL 85-11 (J)
- MRP/MSL 85-15 (J)
- MRP/MSL 85-19 (OP)
- MRP/MSL 85-67 (IR)
- MRP/MSL 85-104 (TR)
- MRP/MSL 85-143 (TR)

(d) Contracts:

- DSS 27ST.23376-5(-5006 to -5009): "Recommended values for Britholite ore OKA-2"
  -5006 Slowpoke Laboratory, Ecole Polytechnique, Montreal
  -5007 EP Radioanalytical Services, Toronto
  -5008 Analytical Services, Saskatchewan Research Council
  -5009 Trace Analysis Research Institute, Dalhousie University
  S.A. - C.W. Smith.

- Reqn. 5-9060 "Homogeneity evaluation of reference ore MA-2A", Chemex Laboratories Ltd.. S.A. - H.F. Steger.

- Reqn. 5-9062 (-1 to -7): "Recommended values for britholite ore OKA-2"
  -1 Bondar-Clegg Ltd. (Vancouver)
  -2 Chemex Labs Ltd. (Vancouver)
  -3 Nuclear Activation Services
  -4 Barringer Magenta Ltd.
  -5 X-Ray Assay Laboratories
  -6 Becquerel Laboratories Inc.
  -7 Materials Research Laboratories
  S.A. - H.F. Steger and C.W. Smith.

- Reqn. 5-9149 "Homogeneity of Zn/Al alloys", Kidd Creek Mines Ltd. Metallurgical Site. S.A. - C.W. Smith.

• **Project 30.69.02:** Analytical Methodology
Project leader : J.C. Hole

Objective:

To develop and improve analytical methods, techniques, and laboratory facilities, mainly in support of CANMET programs, and to participate in working groups and/or serve on committees of national and international organizations which develop and disseminate information on standard analytical methods.

1. Analytical Research and Method Development

(a) Determination of antimony, bismuth, silver, copper, cadmium and indium in ores and concentrates

Atomic-absorption spectrophotometric methods have been developed for the determination of small amounts of antimony, bismuth, copper, cadmium and indium, and for silver, copper, cadmium and indium in ores and concentrates after simultaneous group extraction into methy isobutyl ketone from a sulphuric acid-potassium iodide medium.

(b) Determination of antimony in ores and concentrates by graphite furnace atomic-absorption spectrophotometry

The determination of trace amounts of antimony (and possibly indium, bismuth and tellurium) by electrothermal atomic-absorption spectrophotometry, is under investigation.

(c) Determination of free thiourea in gold leach solutions

A semi-quantitative method, based on ultraviolet spectrophotometric measurement, has been developed for the determination of unreacted thiourea in leach solutions from the processing of chalcopyrite and arsenopyrite concentrates.

(d) Manual of methods for the precious metals

This manual of CANMET methods for the determination of gold, silver, platinum and palladium in ores and related materials has been completed.

(e) Determination of gold in Mint sweeps

A gravimetric method has been developed for the determination of gold in sweeps from the Royal Canadian Mint's gold refining process.

(f) Determination of phosphorus in jarosites

A gravimetric method has been applied to the determination of minor and major amounts of phosphorus in jarosites.

(g) Determination of tellurium in precious metal leach solutions

A hydride-generation atomic-absorption finish was investigated for the determination of tellurium in leach solutions containing gold, platinum and palladium, after the preliminary separation of tellurium.

(h) Characterization of minerals from magnetic properties

A new vibrating magnetometer acquired during the review period has been interfaced to a microcomputer for routine magnetic susceptibility and hysteresis loop measurements. To complement the magnetic susceptibility data, Mössbauer spectroscopy has been used to characterize products from the magnetic separation of coals and uranium tailings.

(i) Determination of rare-earth elements in uranium ore processing solutions by high-performance liquid chromatography

Dynamic ion-exchange HPLC has been applied to the rapid separation and determination of $\geq$0.1 µg/mL of the rare-earth elements and yttrium in solutions from hydrometallurgical processes used for uranium ores. The method is considerably faster than the X-ray fluorescence method and yields comparable results.

(j) Determination of organic acids in lysimeter leach solutions by high-performance liquid chromatography

The use of dynamically-coated ion-exchange columns, coupled with detection by ultraviolet vacancy absorption, has been investigated for the separation and determination of trace concentrations (10^{-4} to 10^{-3} M) of acetic, lactic, propionic and pyruvic acids in leach solutions from Elliot lake uranium tailings.

(k) Determination of sulphoxy anions in cyanide barren effluents and coal desulphurization products by high-performance liquid chromatography

Chromatographic systems, involving reversed phases coated with a permanently sorbed ion-exchanger coupled with indirect ultra-violet detection, are being investigated for the determination of sulphite, sulphate and thiosulphate ions in cyanide barren effluents and products from coal desulphurization studies.

(l) Determination of tri-n-butyl phosphate in solvent extraction effluents by gas chromatography

A gas chromatographic method has been developed for the separation and identification of TBP ($\geq$0.1 ng/mL) and kerosene (Sol-Esso) in effluents from solvent extraction processes.

(m) Inductively-coupled plasma atomic-emission spectrometric analysis

Method development and quantitative calibrations for the sequential ICP spectrometer are continuing on an "as required" basis. Line selection and calibration has been completed for 10 trace elements in uranium processes solutions, for 28 elements at major and trace levels in zinc-, copper- and manganese-aluminum alloys, high alloy steels and cast irons, and for 17 elements at trace levels in environmental and hydrometallurgical materials.

(n) Thermal analysis system

A Dupont 9900 Thermal Analyser was acquired, installed, interfaced with the existing thermobalance and differential thermal analyser, tested and calibrated. The equipment was used to examine samples from various projects and proved to be reliable and convenient.

Patent applications were filed for a modification of the thermal analysis system that provides for concurrent thermogravimetry and differential thermal analysis on two samples under identical conditions, and hence facilitates the correlation of results of the two techniques.

(o) Computerized information system for the Chemical Laboratory

Extensive program modifications were required in the Chemical Laboratory data management system to accommodate the new CANMET project numbering system introduced in April 1985. A new project file PRNOS85 and a routine VALID85 were written to transpose 1984 project numbers to the corresponding 1985 numbers, and modifications were needed in a number of other programs and procedures.

2. Standards Development

(a) ISO/TC 102 (Iron Ores)

Again this year, CANMET has made substantial contributions to this International Organization for Standardization technical committee.

(i) ISO/TC 102/SC 1 (Sampling)

An MSL officer is chairman of the Canadian Advisory Committee (CAC) to this subcommittee, and has been active with the continuing review of standards relating to iron ore sampling.

(ii) ISO/TC 102/SC 2 (Chemical Analysis)

An MSL officer serves on this committee and collaborates with the on-going investigations. Two interlaboratory studies of proposed international standard methods have been completed. Numerous technical documents have been reviewed.

(iii) ISO/TC 102/SC 2/WG 12 (Chemical Analysis - Working Group on Statistics)

An MSL officer serves as convenor of this working group, which evaluates statistically all international tests for the development of standard analytical methods for iron ores. Several sets of international test data were evaluated and reported.

(iv) International data collection and storage

MSL is the international centre for analytical data generated by ISO/TC 102/SC 2 (Chemical Analysis) and SC 3 (Physical Testing). These data are stored in a computer data base created and maintained by MSL officers, and are available to support ISO work.

(b) ISO/TC 69 (Application of Statistical Methods)

This ISO horizontal committee is responsible for the development of ISO standards for statistical methods and to provide guidance to other ISO technical committees on the statistical aspects of their work. An MSL officer serves as the Canadian representative to the working group on the revision of ISO 5725, the standard method for the determination of precision and accuracy of measurement procedures. The same officer also serves a chairman of the Canadian Advisory Committee of Subcommittees 3 and 6.

(c) ISO/TC 183 (Copper, Lead and Zinc Ores and Concentrates)

Two MSL officers are members of the Canadian Advisory Committee to this ISO Committee.

One officer is convenor of Working Group 10 (Statistical Evaluation of Test Programs), and has been active in the evaluation of four international test programs of chemical analysis, and also with the development of standard methods of sampling and preparation of concentrates.

One officer has completed two interlaboratory studies of proposed standard analytical methods, and has reviewed numerous technical documents in the field of chemical analysis.

(d) Computer system for ISO data

Computer programs used for data bases and statistical analysis in the development of ISO standards were converted from FORTRAN 4 to FORTRAN 5 (FORTRAN 77) so that they may be used on the new CSC CYBER NOS/VE system and on a Tektronix computer.

3. Reports:

- MRP/MSL 85-36 (IR)
- MRP/MSL 85-41 (IR)
- MRP/MSL 85-42 (IR)
- MRP/MSL 85-98 (OP)
- MRP/MSL 85-104 (TR)
- MRP/MSL 85-143 (TR)
- MSL 86-5 (IR)
- MSL 86-6 (IR)

• **Project 30.69.03:** Aggregate/Concrete Testing and Standards
Project leader : G.G. Carette

Objective:

To provide technological expertise and information for Canadian and international standards writing organizations concerned with aggregates and concrete, by performing development work on in-situ tests, NDT methods and other tests, by coordinating the CSA Sample Comparative Cement testing program, by organizing conferences on the use of NDT and new concrete materials and by participating in committees of the CSA, ACI, ASTM, ISO, etc.
Aggregates and concrete testing and standards contribute much to ensuring that concrete will perform as specified in construction projects, thus protecting public interest and safety.

(a) Joint comparative CSA Cement Sample Program

At the request of the Committee on Hydraulic Cements of CSA and the Canadian cement industry, a joint project was initiated at the end of 1978 between Canadian cement testing laboratories and CANMET to assess existing cement specifications and testing methods in Canada. CANMET is coordinating the program and is in charge of the overall organization, including the preparation and distribution of test samples and the compilation, analysis and publication of test data. The cement test samples for the program are obtained from the current production of a cement plant selected at random from among the participating companies. Cement sample No. 40 was distributed among 25 laboratories in the country.

Also at the request of the above committee, CANMET is investigating the possibility of setting up a new national monitor cement program for 1986.

(b) 2nd International Conference on the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete

CANMET, in association with the American Concrete Institute, U.S.A., is sponsoring the 2nd International Conference on the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete in April 1986 in Madrid. The final circular which included a list of more than 120 papers to be presented at the conference was issued in late 1985.

(c) International workshop on Alkali Aggregate Reactions in Concrete and Construction and Rehabilitation of Concrete Parking Structures

CANMET sponsored a very successful international workshop on Alkali-Aggregate Reactions in Concrete and Rehabilitation of Concrete Parking Structures in May, 1985 in Montreal. The workshop was attended by more than 200 delegates.

(d) Planning is underway to co-sponsor a two-day workshop on "Concrete for Offshore Structures" to be held in St. John's, Newfoundland in September 1986.

- **Project 30.69.04:** Thermal Shock-Resistant Ceramics
  Project leader : K.E. Bell

Objective:

To gain a better understanding of thermal shock failure and to validate a CANMET-derived theory for ranking thermal shock resistance of ceramic and mineral materials.

Ceramics are inherently brittle materials: by virtue of their lack of ductility they are susceptible to failure under tensile stresses induced by temperature gradients established during heating and cooling. In evaluating existing ceramic materials or new materials under development, it would be useful to have a method for at least ranking comparable materials for resistance to thermal shock. Current methods, e.g., ASTM Spalling Test for Refractories, employ simulated service techniques, are lengthy, laborious and frequently expose the operative to unpleasant working conditions. An existing theoretical method requires the determination of a number of physical and thermophysical parameters between room and high temperatures utilizing a variety of complex equipment found only in the most sophisticated laboratories. Its use is largely restricted to materials for engineering applications in advanced technologies, e.g., space vehicle. A simplified treatment developed in CANMET is based only on the product of thermal expansion and thermal diffusivity, each relatively simple measurements that can be performed with relatively inexpensive equipment. To date, good correlation has been obtained between the predicted thermal shock resistance of a suite of experimental clay flue lining materials and those obtained by empirical test methods.

The CANMET predictive theory is being evaluated against the results obtained by empirical methods for a suite of selected acid and basic refractories. Some variances in ranking according to methodology has further demonstrated the inadequacies of the empirical quenching methods. Owing to time lost in repairing, upgrading and commissioning the thermal diffusivity measuring apparatus, measurement of the thermal properties of the samples will be completed only near fiscal year-end, when a report will be prepared and the Project terminated.

By-Product Recovery

- **Project 30.77.01:** Silver Recovery in the Zinc Industry
  Project leader : J.E. Dutrizac

Objective:

To increase the recovery of silver in Canadian zinc plants to >75%. This will be achieved by elucidating the behaviour of silver in conventional and proposed zinc circuits and by determining the chemical and mineralogical balances of silver in these operations. An equally important objective will be to develop at the bench and mini plant scales, new processing technology to increase silver recoveries in zinc plants by 1987. The success of the project will be measured in terms of scientific reports and of new processing concepts to increase silver recoveries.

Canada in the world's largest supplier of zinc concentrates and is also a major producer of zinc metal. All Canadian commercial zinc concentrates contain potentially recoverable quantities of silver. Current silver recoveries in Canadian plants range from 0 to >90%. Because of the value of the silver byproduct, much work has already been done on silver recovery, and many investigations are in progress but with limited success to date. Thus, there is a genuine need for a thorough and critical examination of the whole problem of silver deportment and recovery in the zinc industry - commencing with the ore and proceeding through the various processing steps to the final products and/or residues.

(a) Mineralogical investigations

Studies on the identification of the mineral forms of silver in zinc concentrates and residues continue. The proton microprobe technique (micro-PIXIE) has been used to detect silver in sphalerite in several zinc concentrates. For example, the presence of ~30 ppm Ag in the sphalerite from Brunswick Mining and Smelting represents about 30% of the silver values in the zinc concentrate from that mill. Pyrite may be a trace silver carrier, but this observation requires confirmation.

Studies on the loss of silver in the jarosite-type compounds formed during zinc processing continue. The conditions affecting silver losses have been defined, and the incorporation of silver in lead jarosites, which are commonly formed in high acid leaching circuits, has been elucidated. Hydronium ion has been postulated to substitute for Ag^+ in jarosite-type compounds, and the existence of H_3O^+ in such compounds was confirmed by NMR magic angle spinning techniques.

(b) Silver in zinc plant residues

The flotation of silver from various zinc plant leach residues and the effect of the leaching parameters on the flotation practice are being pursued via contract. About 75% Ag recovery into a 1% Ag concentrate has been obtained, and the beneficial effects of sphalerite additions were demonstrated. Unfortunately, thorough washing of the residues seems necessary for good silver selectivity.

Several mineralogical studies have been carried out on various conventional and pilot plant leach residues. The association of silver with masses of silica gel was demonstrated, and silver-impregnated silicate grains were observed. Leaching tests suggested AgCl in the calcine but not to the same degree as in the leach residues. The key role of residual sphalerite in collecting silver, as a sulphide rim, in the leaching circuits was illustrated. Figure 12 shows a small grain of residual sphalerite rimmed by a silver-bearing sulphide coating (white). The data suggest the coating has formed during leaching.

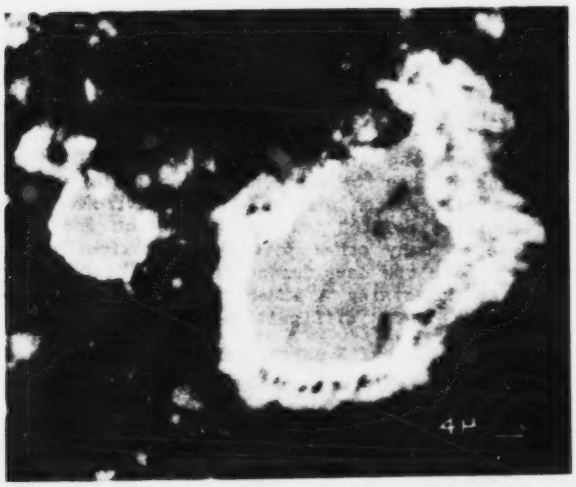

Fig. 12. SEM photomicrograph of grains of residual sphalerite (medium grey) rimmed by silver-bearing sulphide (white) which appears to have formed during leaching

Thermodynamic calculations suggest the presence of metallic silver in the roaster calcine. As an aid to the recovery of such silver, the kinetics of silver metal dissolution in acidic thiourea media were studied, and a report has been drafted. The recovery of silver from thiourea media is currently under study. The presence of AgCl in the calcine is also likely, and the solubility of AgCl in sulphate processing solutions is being examined to aid the understanding of the behaviour of this species.

(c) Zinc electrowinning

A joint CANMET-Cominco project seeks to determine the effect of various impurities on commercial zinc electrowinning practice. This study is part of a continuing project which is being done to optimize the parameters in zinc electrowinning from industrial sulphate electrolyte in order to achieve better control in current plant practice. During the past year, the effects of copper, nickel, cobalt and a series of less commonly encountered metallic impurities on zinc electrowinning were determined. Current efforts are focussing on the effects of thiourea and various flotation reagents on the electrowinning step as such reagents may be used for silver recovery.

(d) Reports:

- MRP/MSL 85-4 (J)
- MRP/MSL 85-81 (OP&J)
- MRP/MSL 85-99 (OP&J)
- MRP/MSL 85-144 (TR)

(e) Contracts:

- Reqn. 3-9052 "Secondary ion mass spectroscopy (SIMS) - study of silver dissolved in sulphide minerals", University of Western Ontario. S.A. - L. Cabri.

- Reqn. 4-9295 "Computation of PIXE analytical data", University of Guelph. S.A. - L. Cabri.

- Reqn. 5-9045 "Recovery of silver from zinc plant residues - Phase II", Noranda Research Centre. S.A. J.E. Dutrizac.

- Reqn. 5-9129 MDA "Gold-silver recovery from zinc pressure leach residues Phase I", Hudson Bay Mining and Smelting Co. S.A. - W. Craigen.

- Reqn. 5-9220 MDA "Metal recovery oxide residues", Hudson Bay Mining and Smelting Co. Ltd. S.A. - W. Craigen.

- Reqn. 5-9264 "Gold/silver recovery from zinc pressure leach (ZPL) residue (phase 2A)", Hudson Bay Mining and Smelting. S.A. - W.J.S. Craigen.

- **Project 30.77.02:** Non-ferrous Metallurgical Slags
  Project leader : A.H. Webster

Objective:

To develop methodology to reduce the loss of valuable metals such as nickel, copper, cobalt and precious metals and to increase the rejection of undesirable elements such as arsenic, bismuth and antimony into slags through better understanding of the factors affecting metal losses to slags, and to recommend practices for control.

Most concentrates of copper, nickel and lead sulphide ores are treated by pyrometallurgical smelting. Many of the concentrates sent for smelting contain minor amounts of valuable metals, for example, cobalt, precious metals, molybdenum and zinc, some of which may be lost to the slag. Methods for decreasing these losses or for recovering the metals from the slag before it is discarded would help conserve Canadian mineral resources by increasing recoveries from the ores.

(a) Recovery of nickel and cobalt from slags by pyrrhotite addition

Industrial discard slags contain various amounts of valuable metals such as nickel, cobalt and copper. In the present study, the possibility of recovering such metal values by addition of pyrrhotite ($Fe_{1-x}S$) to the slag at high temperature and under reducing conditions was examined. A buffer atmosphere containing mixtures of CO_2 and H_2 in argon was maintained above the molten slag to control the oxygen partial pressure. Three industrial slags from electric and reverberating furnaces were examined using various experimental parameters such as oxygen partial pressure, equilibration time, pyrrhotite/slag ratio and sample container (silica or alumina). The results indicated the reversion to the matte ($Fe_{1-x}S$) of 60-70% of the nickel, 40-45% of the cobalt and 65-70% of the copper under optimum conditions. Over the region of oxygen partial pressure examined (log PO_2 = -9 to -11 at 1250°C) there appeared to be little change in the partition of the metals between matte and slag; this partition was comparable to that observed previously under an argon atmosphere. The ferrous/ferric ratios of the slags before and after treatment with pyrrhotite under argon atmosphere were determined by Mössbauer spectroscopy. The relatively high ferrous/ferric ratios indicated that the original slags were quite well reduced.

The treatment of industrial slags with pyrrhotite to extract valuable metals from the slag would have to be followed by further treatment of the matte to recover these metal values. To facilitate this, an attempt is being made to increase the concentration of the desired metals in the matte by recycling the matte. In preliminary experiments the matte was recycled at least three times with fresh slag to determine the increase in concentration of nickel, cobalt and copper in the matte. The experiments were done in silica crucibles in an argon atmosphere at 1250°C with an equilibrium time of 30 minutes.

(b) Selenium distribution in Cu/Cu_2O melts

The presence of relatively high levels of selenium, among other elements, in anode copper causes various operational difficulties in the copper refining stage. The possibility of reducing the amount of selenium in copper by concentrating it in a copper oxide phase, which would later be treated separately, is considered. This route, however, depends on the distribution of selenium between the copper and the copper oxide phases. A study of the distribution coefficient of selenium in Cu/Co_2O melts was undertaken and a technique was developed to allow high-temperature sampling of coexisting Cu and Cu_2O phases to which selenium metal was added. Quenched samples were examined by chemical and electron microprobe analyses. Preliminary results indicated a favourable distribution, but the distribution coefficient was not large enough to be the basis of a method for removing selenium from copper.

(c) Contract:

- Reqn. 3-9172 "To develop a clean smelting process for highly roasted copper-nickel calcines and to improve metal recovery", Falconbridge Ltd. S.A. A.H. Webster.

Environmental Controls

- **Project 30.86.01:** Tailings Characterization and Control Mechanisms
  Project leader : G.M. Ritcey

Objective:

To contribute to the development of methodology for the effective control and disposal of potential environmental contaminants discharged from mine/mill operations.

It is becoming increasingly evident that the existing methods for the containment and disposal of mine-mill wastes are not without environmental difficulties related to acid generation and the release of many other potentially noxious elements. With the development of newly discovered deposits containing a wider range of potential pollutants these difficulties may become more serious.

The most desirable approaches to resolving these problems are those which employ well-known unit processes which can be readily substituted for those presently in use, or added on to existing processes.

CANMET's role will include contributions to the development of new processing steps for the removal of pollutants in mills prior to discharge, the development of methods for the treatment of effluents and the development of methods for containment technology.

(a) Mineralogy

Samples of size fractions of cores taken from a subaereal lysimeter test are being evaluated to compare with surface chemistry, radiometric analysis and magnetic susceptibility.

(b) Lysimeter tests

At present, 32 separate lysimeter leaching tests are in operation to evaluate the effectiveness of

placing wetland (bog) vegetation on the surface of pyrite-containing tailings for the purpose of arresting sulphuric acid generation. Inhibition of bacterial sulphide mineral oxidation, which is the primary cause of sulphuric acid generation, is manifested by effluents from the test lysimeters of near neutral pH containing low concentrations of iron and sulphate. Results to date indicate that sulphuric acid generation is completely arrested by 20-30 cm of wetland vegetation placed on the surface of the uranium tailings from Elliot Lake, and at least four of the seven base metal tailings tested, and that a water table near the tailings/soil interface is necessary to arrest sulphuric acid generation.

(i) Fresh tailings

When 1 tonne of fresh tailings is inoculated with iron-oxidizing bacteria, the pH of the effluents decrease to <5 after ~6 simulated years, and continues to decrease and remain at 2-3. After 20 cm of bog is placed on the surface of the tailings, the pH increased to >6 (with minor exceptions) to the present. A similar response was noted in tailings that had not been inoculated with iron-oxidizing bacteria, and in which these bacteria were inhibited either with hypochlorite or with thymol. In both of these tests, a water table was established ~10 cm below the tailings surface.

(ii) Deep water disposal

Two lysimeters were started during the year to simulate deep water disposal of tailings. Columns are 2 ft diameter x 20 ft high each containing 0.25 tonne Elliot Lake tailings in one column or Noranda pyrite (92%) in the other. The columns are filled with Ottawa river water. Sampling is conducted at different depths of the columns. The data are compared with control lysimeters at normal deposition conditions. After 26 weeks duration the Elliot Lake test has stabilized at a neutral pH; acid generation has commenced in the control. Bacteria population is stable at 10^3 - 10^4 cells/mL. In the Noranda pyrite test, the pH has stabilized at pH 4 (while the control continues to generate acid). Bacteria population is stable at 10^3 - 10^5 cells/mL.

(c) The use of wood waste for acid mine-water pollution-abatement

The combined functioning of the principal pieces of monitoring-control equipment required for a field experiment using wood waste for acid mine-water pollution-abatement, was tested. The results indicate the feasibility of using the selected instrument combination centered around a programmable controller. This testing of equipment was done in view of economy. The specifications defined by the wood waste process could not be fulfilled by commercially-available equipment. A flowmeter covering the wide range of flowrates occurring in the process was designed and constructed. The control instrument specifications were established in the laboratory prior to designing the experimental field arrangement. granular medium having differential-sorptive properties appeared valid. Although the machine used in the method, was originally designed and constructed for polishing the effluents of the wood waste process, the method has a wider application, potentially covering metal separation. The regenerative control of a 5-HP motor appeared satisfactory. However, other parts of the machine require mechanical improvements to reach higher rotational speeds for effective metal separation than can be achieved at present.

(d) Analytical development

(i) Radon-220 and Radon-222 emanation studies

A study of the emanation rate of radon from uranium tailings has shown that a 10-cm dry powdered clay covering reduces the rate by a factor of two but that saturating this layer with water reduced it almost to background level. Replacing the intergranular air with water and denser fluids increases the rate but not in direct proportion to the density of the intergranular medium. The escape of radon from solids is considered to occur during the process of alpha particle decay and work is continuing on this premise.

(e) Contracts:

- Reqn. 4-9319 "To develop a tailings management program plan in relation to acid-generating mine tailings in Canada", Monenco Consultants Ltd. S.A. - E.G. Joe.

- Reqn. 5-9064 "Measurement of anisotropic magnetic susceptibility on tailings cores obtained from the Ontario Research Foundation lysimeter experiment", Morris Magnetics. S.A. - G.M. Ritcey.

The contract has substantiated an earlier contract on magnetic susceptibility measurements and its potential value in the tracing of migration in tailings.

- Reqn. 5-9119 "Ecological engineering research on Inco Limited Levack tailings at Sudbury, Ontario - phase I", Inco Ltd. S.A. - E.G. Joe.

- Reqn. 5-9120 "Hydrogeochemical investigations of reactive sulphide tailings of the Waite Anulet tailings site, Noranda, Quebec - phase I", Noranda Mines Ltd. S.A. - N. Davé.

- **Project 30.86.03:** Water Pollution Control
  Project leader : B.H. Lucas

Objective:

To establish technology for the control of water pollution to meet the standards set by regulatory agencies for the mining and processing of minerals by identifying potential problems and examining methods for the removal of environ-

mental contaminants from metallurgical processes liquid waste streams.

The Mineral Sciences Laboratories have had an interest for many years in the treatment of liquid effluents from the mining industry. These include heavy metals, cyanide, arsenic and thiosalts. Priority will be given to the removal and containments of sludges from the treatment processes to clean up liquid effluents of arsenate, thiosalts, cyanide, heavy metals and other undesirable contaminants.

(a) Thiosalt effluents

The results of CANMET's Thiosalt Program were summarized in a series of publications and presentations, and the program was successfully terminated. Several methods of reducing the thiosalt output of complex sulphide processing mills were identified, but these measures may affect the metallurgical results of the mill in a negative way. Chemical oxidation methods for the elimination of thiosalts from mill effluents were also investigated, and a combination of biological and hydrogen-peroxide oxdation appears to be the best practicable method. Reagent and capital costs, however, remain quite high, so that novel and efficient oxidation methods should further be explored on a more general basis.

(b) Impurity behaviour during iron precipitation

A comprehensive program was carried out to elucidate the behaviour of arsenic during jarosite precipitation. Pentavalent arsenic is readily precipitated during jarosite formation, but most of the arsenic is removed as amorphous or crystalline scorodite, $FeAsO_4.2H_2O$. Only minor amounts of arsenic are incorporated into the jarosite structure. Trivalent arsenic is not precipitated during jarosite formation, and its removal depends on its rate of oxidation to As(V). The conditions for arsenic removal were defined and these have been reported. Current efforts are focussing on phosphate deportment during jarosite formation, and many similarities between AsO_4 and PO_4 have been noted.

(c) Acidification for cyanide elimination

i) Two methods have been applied successfully, on batch scale, for enhancement of the acidification process for cyanide elimination from gold mill barren bleed. Ultrasound produces intense cavitational forces in a solid-liquid milieu which facilitates the evolution of HCN gas. Ion exchange resin removes ions from solution which restrict the dissociation of metallocyanide complexes. Dissociation of these complexes is the route to cyanide recovery for recycle to leach.

ii) Polishing techniques have been demonstrated to be technically viable. Adsorption of a few ppm of metallocyanide which may remain in solution in an acidified and aerated barren bleed was efficiently accomplished by spiking the primary process effluent with metal sulphide floc. Also effective was an alternative destructive technique employing SO_2.

It is planned that some extended work will involve demonstration of continuous-flow sequential steps aimed at minimizing overall residence time, and operating costs, while enabling achievement of an environmentally safe final effluent.

Preliminary work, currently underway, is aimed at determining the technical feasibility of recovering cyanide from the CNS^- ligand. The environmental effect of this pollutant is coming increasingly under scrutiny as potentially hazardous.

(d) Analytical development

(i) Determination of cyanate and thiocyanate in cyanide barren effluents by high-performance liquid chromatography

High performance dynamically-coated anion-exchangers coupled with conductivity detection was applied to the determination of cyanate and thiocyanate ions in cyanide barren solutions. The retention characteristics of the anions were governed by the choice of the eluting co-anion and the concentration of organic modifier employed. Tetrabutylammonium salt was used to condition the column, and salicylate was employed as eluting agent because it provides the necessary eluting strength and results in a low background conductivity.

(e) Reports:

- MRP/MSL 85-44 (IR)
- MRP/MSL 85-81 (OP&J)
- MRP/MSL 85-84 (OP&J)

(f) Contracts:

- Reqn. 3-9044 "Technical and economic evaluation of thiosalt treatment alternatives", Noranda Research Centre, completed. S.A. - J.E. Dutrizac.

- Reqn. 3-9184 "Catalyzed air oxidation of thiosalt effluents using copper sulphide catalysts", Prof. G.L. Rempel, U. of Waterloo, completed. S.A. - J.E. Dutrizac.

- Reqn. 3-9192 "Study of water management in extractive metallurgy", Randal International Ltd. S.A. - B.H. Lucas.

- Reqn. 4-9184 "Bio-destruction of cyanide", Zenon Environmental Inc., completed. S.A. - H.W. Parsons.

- Reqn. 5-9023 "Development of a sampling technique to sample picogram amounts of radioactive and non-radioactive metals from large volumes of water", Monenco Consultants Ltd. S.A. - J.L. Dalton.

- Reqn. 5-9121 "Gold mill effluent treatment utilizing ion exchange technology", (UP-W-258), Wittek Development Inc. S.A. - G.M. Ritcey.

- Reqn. 5-9161 "Generation and stability of mine/smelter effluent sludges", Gimet, Mellor, Liebich Assoc. Ltd. S.A. - B.H. Lucas.

- Reqn. 5-9203 "Application of reverse osmosis to cyanide recovery from gold mill barren bleed", Zenon Environmental Inc. S.A. - V.

- COFE-6-9001 "Development of a high intensity light mediated process for destroying iron cyanide complexes in waste waters", Trojan Technology Inc. S.A. - J. Schmidt, Environment Canada. CANMET observer - V. McNamara.

- **Project 30.86.04:** Air Pollution Control
  Project leader : J.M. Skeaff

Objective:

To evaluate and where feasible to develop effective and acceptable methods for the monitoring and control of noxious elements encountered in Canadian pyrometallurgical processes. Investigations will focus on developing thermal data presently lacking for arsenides and arsenates, as well as methods for eliminating SO_2 from smelter off-gases.

The emissions of noxious elements and their compounds during pyrometallurgical processing of Canadian ores and concentrates is an area of concern to federal and provincial health and environmental protection organizations as well as to private industry. Of particular concern are non-ferrous roasting and smelting operations which result in emissions of SO_2 and of arsenic and mercury and in many cases small quantities of other toxic elements such as cadmium, selenium, tellurium and lead. There is a need for more definitive data on these trace elements in the concentrates and process streams, and on the form in which they are transported. Also required are data for modifying flowsheets or developing pollution abatement equipment for the economic removal and disposal or recovery of these elements, in particular those associated with dusts from smelters which, due to economic or location factors, do not have an acid plant and thus constitute particular problems as to the roasting operations associated with the recovery of gold, silver, nickel and cobalt from arsenical ores.

(a) Thermochemical studies of arsenides and arsenates

Thermochemical and DTA studies are being conducted to determine the thermal properties of arsenides and arsenates (those of Ni, Fe, Cu, Co, Pb, Zn and Ca) at elevated temperatures in order to develop data which will enable the prediction of the behaviour of arsenic-bearing systems in pyrometallurgical processes, e.g. roasting, smelting, refining, etc.

An investigation into the thermochemical properties of certain arsenates is being conducted. The experimental method consists of an equilibrium electrochemical technique in which a partially stabilized ZrO_2-CaO electrolyte is employed in an oxygen concentration cell to measure galvanic potentials. To date, preliminary thermochemical data for the arsenates of nickel and silver have been obtained. The resulting data can be used to predict stable condensed phases and gas compositions occurring under roasting or other pyrometallurgical conditions.

An investigation of the oxidation of niccolite (NiAs) by differential thermal analysis and thermogravimetry has been completed in order to determine reaction mechanisms, and the effect of particle size and oxygen partial pressure. The study has shown that the oxidation of nickel arsenide proceeds via a complex series of reactions from NiAs through the lower arsenides to NiO and, under suitable oxygen partial pressures, nickel arsenates. The results suggest that arsenic will not be readily removed from nickel arsenide-bearing ores or concentrates by roasting and are in concurrence with a study previously reported under this project on the thermochemical properties of the nickel arsenides.

(b) Sulphur dioxide capture by solid materials

A study was undertaken to determine the capacity of the mineral pyrrhotite (FeS) to capture SO_2 gas and form elemental sulphur and magnetite (Fe_3O_4).

The interaction of SO_2 with the mineral pyrrhotite from two different sources and a pyrrhotite concentrate from the milling of a Ni/Cu ore was thus studied in the temperature range 600°-750°C in a small fluidized bed reactor. In this temperature range, the reaction occurs with the formation of gaseous sulphur and magnetite. The influence of parameters such as the particle size and the source of pyrrhotite, fluidized bed depth and SO_2 concentration (in SO_2/N_2 mixtures) was examined. The extent of the reaction was found to be very small, particularly at low concentrations of SO_2 (5-10%). The results are interpreted in terms of predominance area diagrams calculated for iron oxides, sulphides and sulphates at various temperatures.

(c) Contracts:

- Reqn. 4-9213 "Development of a solid state arsenic probe for use in pyrometallurgical processes", J. Kirchnirova and C.W. Bale, Ecole Polytechnique, Montreal. S.A. - J.M. Skeaff.

- **Project 30.86.05:** National Uranium Tailings Research Program
  Project leader : R. John

Objective:

The Modelling activity is central to the Program, but it is dependent on research into fundamental understanding of the science to develop its pre-dictive equations. It is also dependent on the input of measured values to calibrate and validate the models developed. Additionally, the disposal technology options must be understood to evaluate the consequences of each option and the relationship of performance to cost. Therefore, the Program has been organized into the following major sections: Modelling, Disposal Technology, and Measurements and Fundamental Understanding.

(a) Modelling

Because of the complexity and uncertainty involved, the NUTP is taking a two-level approach to mathematical modelling. This approach is shown schematically in Figure 13 and involves a series of separate component models at the detailed technical level and a simplified system model linking the components together. The system model does not attempt to couple the component models directly, but couples instead simple models derived from the aggregate results of the more complex component models. In doing this, the NUTP can strive to:

i) provide a sound scientific basis for component modelling and develop certain specific models;

ii) provide a methodology and a framework (i.e. a systems model approach) for integrating these, making long-term predictions and answering cost-effectiveness questions and,

iii) provide a general picture for certain types of Canadian tailings and various disposal options.

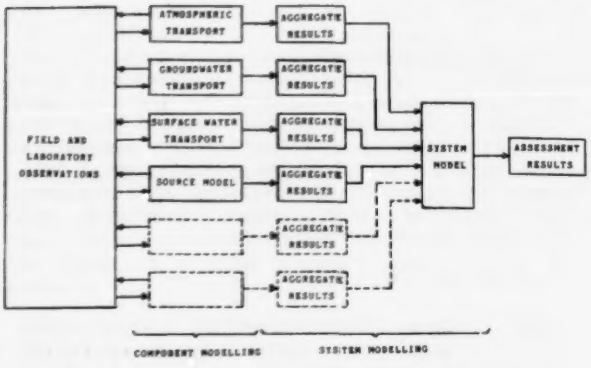

Fig. 13. Model development strategy

By 1985, the second phase of the system model development had been completed. This resulted in UTAP (Uranium Tailings Assessment Program). This model will predict into the far future the dose to man from selected radionuclides, pH surface water systems, and concentrations of such chemical species as sulphate. The model is adaptable to various technology options. It lacks some pathways and radionuclides, and needs additional development for correlated parameters, etc. This will be done in 1986/87.

Contracts:

- DSS OSQ85-00182 "Probabilistic model developments for the assessment of the long-term effects of uranium mill tailings in Canada - Phase III", SENES Consultants Limited. S.A. - R.W. Holmes.

- DSS OSQ85-00207 "Demonstration of the probabilistic system model for the assessment of the long-term effects of arsenic/nickel rich uranium mill tailings deposits in Canada", Beak Consultants Limited. S.A. - R.W. Holmes.

- DSS OSQ85-00225 "Risk assessment for Canadian uranium mill tailings - Phase II", SENES Consultants Limited. S.A. - R.W. Holmes.

- DSS OSQ85-00293 "Comparison of the National Uranium Tailings Program's probabilistic model (UTAP) with the Syvac Computer code of Atomic Energy of Canada Limited", Atomic Energy of Canada Limited (WNRE). S.A. - R.W. Holmes.

Contract Reports:

- DSS OSQ84-00033 "Scientific evaluation of the data in the Canadian uranium tailings database - Phase I and II", IEC Beak Consultants Limited. S.A. - R.D. John
  Micromedia Order Number: 85-5928

- DSS 1SQ84-00048 "Descriptive algorithm development for physical, chemical and biological kinetics operating in uranium mill tailings", IEC Beak Consultants Limited. S.A. - W.C. Harrison and R.W. Holmes.

- DSS OSQ84-00198 "Development of a discussion paper on De Minimis (or Trivial) levels for contaminant concentrations or doses", SENES Consultants Limited. S.A. - W.C. Harrison
  Micromedia Order Number: 85-5174

- DSS OSQ84-00207 "Probabilistic model development for the assessment of the long-term effects of uranium mill tailings in Canada - Phase II", SENES Consultants Limited, S.A. - W.C. Harrison and R.W. Holmes.
  Micromedia Order Number: 86-0654

- DSS OSQ84-00335 "Approaches to risk assessment for Canadian uranium mill tailings", SENES Consultants Limited. S.A. - W.C. Harrison and R.W. Holmes.
  Micromedia Order Number: 86-0657

(b) Disposal Technology

The Disposal Technology section of the work is concerned with the actual physical placement of tailings after close-out. The NUTP has concentrated its efforts into technology that is or has been used in Canada. The evaluations of the technology have adopted three points of view: scientific integrity, the effectiveness in reducing contaminant concentrations and the costs. Subject areas such as liners, both natural and artificial, pyrite oxidation, consolidation, tailings covers and stability of structures have been or are being investigated.

It is particularly important to develop a knowledge of a new technology being used in Saskatchewan. These deposits are complex ores with poorly understood tailings chemistry. The tailings management programs use new concepts which are meant to be more effective at reducing the migration elements of concern. The Disposal Technology section is trying to develop a sound understanding of the mechanisms and reactions taking place, and the potential for future effects. This is being done as a major field study at the Key Lake uranium mine.

Contracts:

- DSS OSQ85-00130 "Monitoring of layered uranium tailings - Phase II", Knight & Piesold Limited. S.A. - D.G. Feasby.

- DSS OSQ85-00227 "Stability of structures for uranium mill tailings retention", Steffan, Robertson and Kirsten (B.C.) Inc. S.A. - D.G. Feasby.

- DSS OSQ85-00218 "Consolidation of uranium mill tailings", Geocon Inc. S.A. - D.G. Feasby.

- DSS OSQ85-00226 "Review of the technology of earth covers for inactive uranium mill tailings in Canada", Steffan, Robertson and Krsten (B.C.) Inc. S.A. - D.G. Feasby.

- DSS OSQ85-00299 "Alternative uranium ore processing technology", SENES Consultants Limited. S.A. - D.G. Feasby.

Contract Reports:

- DSS OSQ84-00085 "Monitoring of layered uranium tailings - Phase I", Knight & Piesold Limited. S.A. - D.G. Feasby
Micromedia Order Number: 85-5930

(c) Measurements and Fundamental Understanding

The Measurements section has two functions. The first is to provide input data for model calibration and validation. This data has been collected under a number of field programs funded by the NUTP. The second section of the Measurements program is the development of fundamental understanding of the pathways used by radionuclides towards mankind.

Of key importance here, is the chemistry of the source terms. Understanding the chemistry of radium and the other radionuclides is essential to designing a model that can be applied over the long-term. As much as possible, the Program is trying to define the chemistry within the tailings pile, including the interactions between the various components. Of particular interest for the Elliot Lake region is the oxidation of sulphur-bearing minerals, including the role played by bacteria.

Although atmospheric dispersion modelling has been well studied, these models require air column field data as input. The NUTP have been investigating the suspension of dust from the tailings surface with a view to developing a predictive model that will provide the input data required by the atmospheric dispersion models from tailing surface characteristics.

Radon has always been the key issue when assessing the impact of tailings placement. A contract to show the dispersion of radon at Elliot Lake will be completed in early 1986. The project to investigate the effect on release rate of radon by vegetating the surface of the tailings was completed in early 1985, and showed that under Canadian conditions vegetation has relatively little effect. It is likely that the major controlling factor is the moisture content of the tailings. Only in climates where revegetation is able to reduce the water level significantly, will there be an effect on radon release.

The NUTP sees sedimentation as being a major sink for radionuclides. Therefore, a series of contracts have been awarded to study various aspects of the sedimentation process. This includes an investigation of the re-mobilization mechanisms of radionuclides from the sediments after mining and milling have ceased.

Contracts:

- DSS OSQ85-00181 "Geochemical behaviour of various non-radionuclide contaminants in uranium mill tailings", Beak Consultants Limited. S.A. H.F. Steger.

- DSS OSQ85-00213 "The fate of radium in uranium leaching and its consequent dissolution mechanisms", Chemex Labs Limited. S.A. - H.F. Steger.

- DSS OSQ85-00219 "Study of the solubility of radium-226 in sulfate media", Chemex Labs Limited. S.A. - H.F. Steger.

- DSS OSQ85-00237 "Estimation of the limits for acid generation by bacteria assisted oxidation in uranium mill tailings", SENES Consultants Limited. S.A. - H.F. Steger.

- DSS OSQ85-00247 "Investigation of bacteria-catalyzed reactions occurring in uranium mill tailings at low oxygen levels", Dobrocky Seatech Limited. S.A. - H.F. Steger.

- DSS OSQ85-00289 "Study of radium-226 co-precipitates in uranium mill tailings by secondary ion-mass spectrometry", Atlantic Nuclear Services Limited. S.A. - H.F. Steger.

- DSS OSQ85-00306 "Study of radiobarites in uranium mill tailings", Beak Consultants Limited. S.A. - H.F. Steger.

- DSS OGS85-00403 "Speciation of arsenic and nickel in sediments in Moira Lake", AECL/CRNL S.A. - H.F. Steger.

Contract Reports:

- DSS OSQ83-00241 "Determine the distribution of radionuclides in aquatic organisms and their environment, and develop transfer coefficients - Phase I and II. SENES Consultants Limited. S.A. - R.D. John
Micromedia Order Number: 85-5927(I), 85-5173(II)

- DSS 1ST83-00325 "Leachability of radium-226 from barium-radium sulphate sludges", University of Alberta. S.A. - R.D. John.
Micromedia Order Number: 86-0650

- DSS 1SQ84-00055 "Study of geochemical mechanisms controlling radium-226 dissolution in uranium mill tailings", IEC Beak Consultants Limited. S.A. - W.C. Harrison/R.W. Holmes.

- DSS OSQ84-00074 "A study of naturally-occurring radionuclide bearing deposits at Portland Creek, Newfoundland", CBCL Limited. S.A. - R.D. John.

- DSS OST84-00190 "Investigation of aquatic communities exposed to uranium tailings seepages (Elliot Lake)", Laurentian University. S.A. - R.D. John/H.F. Steger.

- DSS OSQ84-00195 "National uranium tailings program - Gunnar Field Study", B.B.T. Geotechnical Consultants Limited. S.A. - D.G. Feasby.

- DSS OSQ84-00196 "National uranium tailings program - Lacnor Field Study", Golder Associates Limited. S.A. - R.D. John/H.F. Steger.

- DSS OSQ84-00229 "1984 geochemical study of the acidic contaminant plume near the Nordic Main Uranium Tailings Impoundment, Elliot Lake, Ontario", Morwijk Enterprises. S.A. - R.D. John.
Micromedia Order Number: 85-4599

- DSS OSQ84-00297 "Literature review for National Uranium Tailings Program (NUTP) - Sedmentation Study", Monenco Consultants Limited. S.A. - R.D. John.

- DSS OSQ84-00305 "A review and assessment of the known naturally-occurring concentrations of radionuclides", MacLaren Plansearch Inc. S.A. - G.A. Tremblay.

- DSS OSQ84-00360 "The roles of biological organisms in the removal of radionuclides from surface waters", Monenco Consultants Limited. S.A. - R.D. John.

- DSS OSQ84-00361 "Speciation and absorption/desorption mechanisms of radionuclides on lake sediments", Monenco Consultants Limited. S.A. - R.D. John.

- DSS OSQ84-00416 "Investigations on radiocation speciation and its environmental consequences", Dobrocky-Seatech Limited. S.A. - R.D. John/H.F. Steger.

Fluidized-Bed Combustion

- **Project 50.62.01:** Bubbling Bed Performance Parameters
  Project leader : F.D. Friedrich (ERL)

Objective:

To delineate parameters influencing the performance of Canadian coals and other solid fuels; to characterize the sulphur sorbent performance of Canadian limestones; to advance the level of knowledge concerning fundamental mechanisms of FBC.

(a) Characterization of the sulphur sorbent performance of Canadian limestones

The work on characterizing limestones as SO_2 sorbents in bubbling fluidized beds is a continuation of work from last year. Tests in a bench scale fluidized bed reactor have been completed and a draft report written on the effect of coal ash on the sulphation behaviour of limestones. It has been found that sulphation capacity is adversely affected by the iron oxide content of the coal ash and that different limestones react differently to the iron content.

(b) Characterization of reaction products from fluidized bed combustion

This study involved developing a thermal analysis technique to evaluate sulphated limestone - ash residues from fluidized bed combustors. By varying the test atmosphere and using both differential thermal and thermal gravimetric analyses, accurate determinations of unreacted carbon and limestone can be made. Standard chemical methods have great difficulty differentiating between carbon and carbon dioxide. These analyses are very important in determining the efficiency of FBC units.

- **Project 50.62.03:** Circulating Bed Combustion Systems

  Project leader : F.D. Friedrich (ERL)

Objective:

To design and erect a circulating fluid-bed pilot plant; to identify and accelerate potential industry applications for CFBC.

(a) Vanadium and sulphur capture from byproduct coke

MSL's portion of this project is to investigate emissions of SO_2, heavy metals (V,Ni), and alkali (Na,K), their capture with limestone and corrosive effects from the combustion of tar sands byproduct coke in a circulating fluid bed unit. A 50 kw unit was designed and built. There were considerable problems with the electrical system used for preheating, and with the recycle line configuration. These necessitated redesigns and modifications which delayed the project. However, the unit has been operated for about 200 h using coal, coke and a sulphide gold concentrate as fuel.

Syncrude coke was combusted with limestone sorbent successfully in several trials. The SO_2 capture averaged 90% while vanadium was 95%. There was a light deposit on metal probes which contained 20% Ca and 0.5% V but there was no evidence of corrosion. A paper describing the facility and these very preliminary results was presented at the CANMET Oil and Gas Conversion Contractor Review Meeting in Toronto in November.

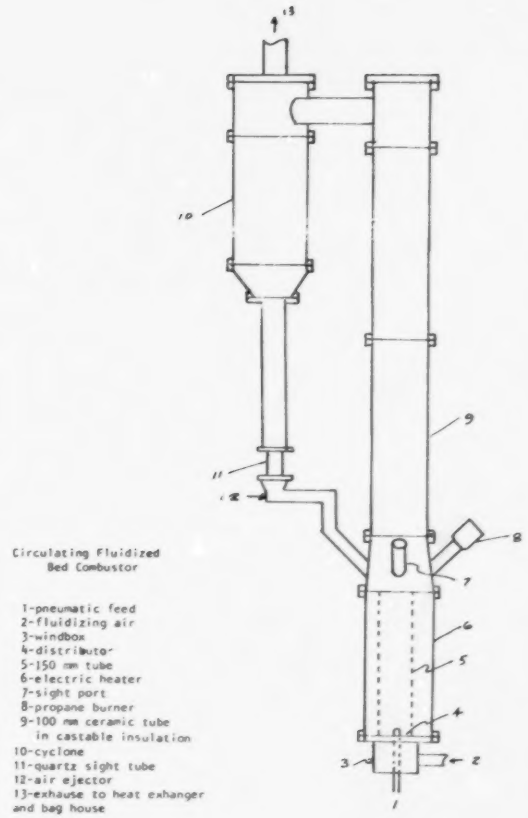

Fig. 14. Circulating fluidized bed combustor

PART B. GENERAL SERVICES AND OPERATIONS

CHEMICAL LABORATORY

Manager: R.G. Gabourin

Summary of Analytical Services

The figures tabulated below refer to the number of analyses performed by the Chemical Laboratory in support of CANMET programs in the period from April 1, 1985 to March 31, 1986.

Sub-sub-Activity	Ores and Fire Assay Section	Metals and Alloys Section	Research Sections: Reference Materials Special Reports	Solution Chemistry Section	Spectrochemistry Section: Optical Emission Neutron Activation	XRF, Radiometry Fluorimetry	Umpire Analysis	Totals
Mining								
14.39	40	-	-	-	-	6	-	46
Coal Mining and Preparation								
20.79	-	19	-	-	-	-	-	19
Mineral Processing								
30.05	32	-	-	16	-	-	-	48
30.13	582	36	4	4	19	79	-	744
30.21	609	-	20	-	299	1884	-	2812
30.29	32	-	-	-	34	6	-	72
30.37	8	-	-	67	-	-	-	75
30.45	58	-	-	2029	44	-	-	2131
30.52	2812	127	117	7300	922	392	-	11670
30.61	227	261	166	1062	124	3046	216	5102
30.69	234	24	-	-	284	128	-	670
30.77	1227	15	-	272	176	26	-	1716
30.86	690	596	-	3552	789	951	-	6578
Fuels Technology								
50.62	80	5	-	4	4	-	-	93
Metals and Materials								
70.04	2	925	-	-	4271	240	-	5438
70.18	-	60	-	-	229	-	-	289
70.27	-	70	-	-	1738	-	-	1808
70.54	-	402	-	-	1337	-	-	1739
70.65	42	4	-	-	265	135	-	446
70.88	36	919	-	27	1551	-	-	2533
Totals	6711	3463	307	14333	12106	6893	216	44029

EXTRACTIVE METALLURGY LABORATORY

Physical Chemistry Section

Head: A.H. Webster

(a) Thermal Analysis

Sub-sub-Activity	No. of Tests
30.13	12
30.29	1
30.86	7
50.62	25
Total	45

(b) Computer Programming

Sub-sub-Activity	No. of Tests
30.13	2
50.62	6
Total	8

MINERAL PROCESSING LABORATORY

Mineralogy Section

Head: P.R. Mainwaring

Summary of Mineralogical Services

Sub-sub Activity	SEM (Jobs)	Total Probe (Jobs)	Image Analyser (Jobs)	X-ray Diffraction (Jobs)
14.25	-	-	-	18
14.39	-	-	-	39
20.56	-	13	-	-
20.79	-	9	-	10
30.05	21	17	17	267
30.13	4	0	21	18
30.21	2	0	1	115
30.29	13	1	-	98
30.37	8	90	-	21
30.45	1	0	-	-
30.52	24	13	-	20
30.61	2	0	1	30
30.69	3	3	-	-
30.77	17	10	-	520
30.86	3	5	-	50
50.17	-	2	-	-
50.46	-	-	-	4
50.62	-	-	-	1
70.65	-	-	-	32
Totals	98	163	40	1243

Lapidary, Mineral Separation and Other Services

Services	No. Completed
Polished Sections	1666
Thin Polished Sections	191
Magnetic Separations	9
Crushing and Screen Analyses	60
Heavy Liquid Separations	26
Low-Temperature Ashing	60
Synthesis of Standards	5

COST RECOVERY CONTRACTS

025145 S - Bentonites as plasticizers in brick shales

025185 S - Chevron gold ore

025189 S - Examination of Westarm Cu-Zn ore and Nor-Acme Au ore

025193 S - Beneficiation of talc

025205 S - Image analysis of complex base metal ores

025206 S - Image analysis study of pyrrhotite concentrate

025208 S - Mineralogical studies of Tally Pond ore, Newfoundland

025209 S - Image analysis study of sphalerite liberation

025211 S - Consolidated Cinola Mines gold recovery

025214 S - Quantitative mineralogical study of Be-Y ores

025215 S - Characterization and expected recovery of tin minerals in Victoria Lake, N.B. sample

025216 S - Jarosite in nickel-copper sulphide leach residues

025220 S - Image analysis study of niobec ore

025221 S - Mineralogical/SEM examination of sands

025222 S - Gold recovery from Hedley Mascot Mill tailing

025223 S - Image analysis of massive sulfide

025224 S - Mineralogical characterization of gold in iron ore

025225 - Recovery of gold from tailing pond - Fenway Resources

025226 S - Mineralogical study of a sample from the Smithers area of B.C.

025232 - X-ray diffractometer analysis of 11 samples

025233 - Solvent extraction crud

025234 - Provide facilities for evaluation of Ontario clays

025235 - Inhibiting kiln scumming in clay brick

025236 - On-going studies related to plant productivity

025237 - Image analysis study of samples from the matte separation circuit of the Inco smelter

025238 - Characterization of fly-ashes

025240 - Analysis of 28 samples for 4 radioisotopes by high-resolution gamma-ray spectrometry

025241 - Characterization of gold in Toronto rubbish

025242 - Image analysis of sulphide flotation product (Portugal)

025243 - Sampling and recovery of gold and silver from Royal Mints Sweeps

025245 - Esso Minerals Canada, Vancouver, B.C.

025246 - Niobec, St-Honore, Quebec

025247 - Plastograph evaluation of clays

025248 - Magnetic separation of a jig concentrate from Monopros Ltd.

025249 - Niobec, Les Services TMG Inc., St-Honore, Quebec

025250 - Mineralogy and image analysis study

025251 - Shirleys Bay - mass concrete pad

025252 - Surface area measurement of treated clays

025253 - Characterization of silicon carbides

025254 - East Kemptville tin

Notes: S indicates an investigation under the START (Short-Term Assistance in Research and Technology) Program

PROGRAM FOR INDUSTRY/LABORATORY PROJECTS (PILP)

- Project No. 37	Underground Biological In-Place Leaching of Uranium Ore	Denison Mines	S.A. - M. Campbell
- Project No. 442	Development of Solid Sodium Electrolytes	Almax Ind.	S.A. - T. Wheat
- Project No. 634	Cement-based Dry-bagged Construction Products	Target Products & Levelton Assoc.	S.A. - H. Wilson
- Product No. 722	Wet Processing of Asbestos	Brinco Mining (Cassiar Div.)	S.A. - G. Riley
- Product No. 723	Silica Fume Shotcrete	Target Products & Hardy Assoc.	S.A. - H. Wilson
- Product No. 870	D.C. Plasma Arc Furnace	Inco Ltd.	S.A. - J. Skeaff
- Product No. 938	Low Permeability Fibrous Concrete	Gemite Unique Products Inc.	S.A. - M. Malhotra

SPECIAL PROJECT

Nonferrous Smelter Study

• Project Leader: W.J.S. Craigen

Objective:

This project is in response to a request from MPS for CANMET's technical contribution into an overall study on the economic, technical and environmental aspects of Canada's non-ferrous smelter industry. The study reviews the productivity and international competitive position of Canada's non-ferrous smelting industry, the impact of more stringent environmental controls on the long term viability of the industry, the economics of modernization/pollution abatement investments and the scope for government action in alleviating the problems of this important Canadian industry. A review of longer-term R&D requirements is also being undertaken on a site-specific basis, to facilitate the selection of the most attractive technologies for both present and future smelter operation in Canada.

Status:

The original objectives of the "Nonferrous Smelter Study" have, for the most part, been achieved with the publication of two EMR special reports; one on nickel and copper, published in May, 1985. CANMET was responsible for two chapters in these reports; "Technological Review and Assessment" and "New Directions for Research and Development". Major emphasis in this project is now being directed towards implementation of the technology development initiatives documented in the EMR reports, and described in more detail on a site-specific basis in CANMET Technological Profile reports in Canada's non-ferrous smelters.

At present, government assistance to facilitate initiation of the technology development projects is being obtained from the following sources: DRIE, IRDP; Federal/Provincial MDA's; Unsolicited proposals (CANMET/DSS) and PILP.

An interdepartmental "Smelter Modernization Co-ordinating Committee has been formed, comprising members from DRIE, EMR and EC. This committee is responsible for negotiating with the provinces and industry to establish procedures, time-frames and funding mechanisms (both capital and R&D) for smelter modernization in Ontario, Quebec and Manitoba. CANMET is represented on a technical advisory sub-committee, and is responsible for chairing or co-chairing all technical meetings with the provinces and industry and advising the co-ordinating committee on the technical and economic aspects of proposed modernization alternatives.

CANMET "Technological Profile Reports" on Inco Sudbury (June 1984), HBMS (June 1985), and Inco Thompson (July 1985) have been completed and released for publication. A report on Falconbridge was also completed in 1985, but has not yet been released for publication, pending approval from Falconbridge.

A summary paper on the EMR Smelter Study was presented at the CIM Annual General Meeting in Vancouver, in April 1985.

The engineering and economic evaluation of the zinc pressure leach (ZPL) process for application at Flin Flon was completed by HBMS (under DRIE, IRDP) and presented to provincial and federal government personnel in January 1986. HBMS is presently developing a proposal for government financial assistance to implement the technology.

Testwork and flowsheet development on the application of the GCM Hydrometallurgical Copper Process to HBMS Copper concentrates have been completed by Bacon Donaldson, and a presentation was made in Flin Flon in January 1986. Although the technical feasibility of the process has been reasonably well proven, economic viability will be primarily dependent on producing a high purity copper product. HBMS, with CANMET assistance, is presently carrying out a more detailed engineering and economic evaluation of the process.

The above project is being funded under the Manitoba MDA. Other smelter development projects which have been initiated in 1985/86 under the Manitoba MDA for which CANMET is responsible, are as follows:

Pyrrhotite Rejection - Inco Thompson
Gold/Silver Recovery from ZPL Residues - HBMS
Metal Recovery from Oxide Residues - HBMS

Two Falconbridge proposals, one on "Pyrrhotite Rejection" and one on "Converter Slag Cleaning" have been approved for DRIE, IRDP funding. A third Falconbridge proposal, (Increased Roast) has been approved by CANMET and is pending a decision on IRDP support.

A new Ontario control order covering 1994 target SO_2 emission levels for Inco, Falconbridge, Algoma (Wawa) and Ontario Hydro has recently been released. The control order allows a three year period for R&D so that the companies can develop the most cost effective technology for achieving the environmental goals.

Ontario has requested that Algoma Steel's Wawa iron ore plant be eligible for federal government financial assistance under the smelter modernization program. Wawa modernization is based on a flotation/magnetic separation process which has been developed and tested over the past year with EMR (IERD) financial assistance.

The Smelter Modernization Co-ordinating Committee (SMCC), has held three meetings with Ontario government personnel to discuss procedures, timeframes and financial committments (capital and R&D) for industry proposed smelter modernization concepts to meet SO_2 emission regulations. Similar meetings were held with Quebec government personnel on the Noranda Horne Smelter modernization.

The technical advisory sub-committee met with Noranda/Fenco Lavalin and Quebec government personnel in November, 1985 regarding the Horne Smelter modernization. Because of the very high cost of the acid plant the committee recommended that an extension to the present study be considered to determine the minimum acid plant costs based on criteria which would achieve the control order objectives for SO_2 emissions, without constraining the smelter's ability to operate in the most productive mode. However the Quebec government took a rather firm stand, requiring Noranda to meet the regulations by 1990 based on the present wording of the control order.

Two CANMET shared costs contracts with Inco Sudbury were initiated in 85/86. Both relate to smelter/refinery modernization but neither has any effect on SO_2 emissions. The projects are:

- Copper Refinery Electrolyte Contract (CANMET/DSS)

- Plasma Furnace Technology for Nickel Production (CANMET/PILP)

A CANMET/DSS shared cost contract with Kidd Creek Mines (KCM) and Sherritt Gordon has been initiated to increase metal recoveries (Zn, Pb, Ag, Cu) from KCM ore, and to decrease the lead content of copper smelter feed.

An unsolicited proposal has been submitted by Nova Pb, a Montreal based secondary lead producer, to assist them in evaluating their rotary kiln process for treating Noranda Horne smelter dusts. If successful the project could eliminate impurity build-up problems at the Horne smelter and facilitate reactor operation at high throughputs; allow Nova Pb to diversity, increase kiln utilization and possibly treat other sources of lead bearing dusts and residues, and reduce Nova's dependence on battery scrap and lead markets and prices for survival.

CANMET is presently investigating the most appropriate mechanism for supporting the proposal.

Based on a recent visit to the QSL demonstration plant in Germany, a preliminary evaluation of the incentives and commercial implications for adopting the QSL process for lead smelter modernization in Canada has been documented. Both BMS and Cominco are presently evaluating the QSL technology for application at Belledune and Trail, and an assessment for the QSL versus the Kivcet and Outokumpu processes is expected within three to six months, after which a decision on lead smelter modernization may be forthcoming.

During 1985/86 CANMET has continued to be involved in a technical advisory capacity to RPC and to Enhanced Recovery Systems (ERS) on the operation of the SRL process pilot plant at Chatham, N.B. The plant began operation in August 1985. The majority of the operating problems have now been resolved and integrated runs of adequate duration to evaluation the process are scheduled to take place within the next few months.

A paper on the "Economic Incentives for the Production of Bulk Base Metal Sulfide Concentrates" was presented at AIME Symposium on Complex Sulfides, San Diego, California, November, 1985.

Report:

- MRP/MSL 85-130 (OP)

PART C. STAFF ACTIVITIES

TECHNICAL COMMITTEES

INTERNATIONAL

International Organization for Standardization

Barkley, D.J.
- Member, CAC/ISO/TC 26/SC 1, Copper and Copper Alloys;
- Member CAC/ISO/TC 17/SC 1, Analysis of Steel and Cast Iron.

Bell, K.E.
- Member, CAC/ISO/TC 33, Refractories;
- Member, CAC/ISO/TC 166, Ceramic Ware in Contact with Foods;
- Member, CAC/ISO/TC 107/SC 6, Metallic and Other Inorganic Coatings.

Chen, T.T.
- Member, CAC/ISO/TC 175, Fluorspar.

Graham, J.A.
- Member, CAC/ISO/TC 183, Copper, Lead and Zinc Ores and Concentrates.

Hole, J.C.
- Member, CAC/ISO/TC 102, Iron Ores.

Mainwaring, P.R.
- Member, Joint CAC/ISO/TC 146/147/SC 3, WGI, Detection Asbestos Fibre in Air.

Malhotra, V.M.
- Chairman, CAC/ISO/TC 71, Concrete (SC 1 and SC 3).

Riley, G.W.
- Chairman, CAC/ISO/TC 102, Iron Ore (SC 1, SC 2, SC 3 and SC 5);
- Chairman, CAC/ISO/TC 56, Mica;
- Member, CAC/ISO/TC 24, Sieves, Sieving and Other Sizing Methods;
- Member, CAC/ISO/TC 146, Air Quality, Workplace;
- Chairman, CAC/ISO/TC 146/SC 2/WG 5; Inorganic Fibres;
- Member, CAC/ISO/TC 77, Asbestos.

Sabourin, R.G.
- Chairman, CAC/ISO/REMCO, Reference Materials;
- Member, CAC/ISO/TC 17/SC 1, Analysis of Steel and Cast Iron.

Steger, H.F.
- Member, CAC/ISO/REMCO, Reference Materials.

Sutarno, R.
- Member, CAC/ISO/TC 102, Iron Ore;
- Chairman, CAC/ISO/TC 102/SC 1, Sampling Subcommittee;
- Convener, ISO/TC 102/SC 2/WG 12, Chemical Analysis Subcommittee, Working Group on Evaluation of Statistical Data;
- Canadian Representative to Study Group on Reference Materials - Iron Ores, CAC/ISO/TC 102/SC 2;
- Member, CAC/ISO/TC 69, Application of Statistical Methods;
- Chairman, CAC/ISO/TC 69/SC 3, Application of Statistical Methods in Standardization;
- Chairman, CAC/ISO/TC 69/SC 6, Application of Precision Data;
- Canadian Representative to ISO/TC 69/SC 6/WG 1, Revision of ISO 5725;
- Canadian Representative to ISO/TC 69/SC 6/WG 2, Acceptability of Observations;
- Convener, ISO/TC 69/SC 6/WG 4, Joint Working Group between ISO/TC 69 and ISO/REMCO on Statistical Aspects of Reference Materials;
- Convener, ISO/TC 183/WG 10, Statistical Evaluation of Test Programs;
- Member, CAC/ISO/REMCO;
- Member, CAC/ISO/TC 183, Copper, Lead and Zinc Ores and Concentrates.

Wilson, J.M.D.
- Member, CAC/ISO/TC 24, Sieves, Sieving and Other Sizing Methods;
- Member, CAC/ISO/TC 102, Iron Ores (SC 3 and SC 5).

International Mineralogical Association

Cabri, L.J.
- Canadian Representative, Commission of Ore Microscopy.

Chen, T.T.
- Member, Committee on Sulphosalts.

International Committee on Applied Mineralogy in the Mineral Industry

Petruk, W.
- Canadian Representative;
- Liaison Representative.

Miscellaneous

Ahmed, S.M.
- Canadian Technical Contact Person to the International Energy Agency for Task VI (Photocatalytic Water Electrolysis) of the Program of Research and Development on Production of Hydrogen from Water.

Cabri, L.J.
- Co-chairman, 4th International Platinum Symposium, Organizing Committee.

Carette, G.G.
- Member, 2nd International Conference on the Use of Fly Ash, Slag and Silica Fume, Madrid, 1986.

MacKinnon, D.J.
- Member, Editorial Board, Hydrometallurgy, Elsevier Publishing Co., Amsterdam.

Malhotra, V.M.
- Chairman, 2nd International Conference on the Use of Fly Ash, Slag, and Silica Fume, Madrid, 1986;
- Member, International Union of Testing and Research Laboratories for Materials and Structures (RILEM);
- Member, Committee 42 CEA, Early Strength Development of Concrete;
- Member, Committee on NDT of Concrete.

Mirkovich, V.V.
- Director, International Thermal Conductivity Conference;
- Member, Editorial Board, International Journal of Thermophysics, Plenum Press, N.Y.

Parsons, H.W.
- Member, Editorial Board, Hydrometallurgy, Elsevier Publishing Co., Amsterdam.

Petruk, W.
- International Conference on Applied Mineralogy in the Mineral Industry.

Ritcey, G.M.
- Member, International Solvent Extraction Technology Committee;
- Editor, International Journal of Hydrometallurgy, Elsevier Pub. Co., Amsterdam;
- Member, Editorial Board, Journal of Separation Process Technology, C. Lildwell Press, England;
- Member, Editorial Board, "Science and Technology of Tributyl Phosphate", C.R.C. Press, Pub."
- Member, Editorial Board "Extractive and Process Metallurgy", Gorden & Branch, Pub.

Sirois, L.L.
- Member, International Scientific Committee of the International Mineral Processing Congress.

Soles, J.A.
- Member, Process Mineralogy Committee, AIME:
- Member, Organizing Committee, 7th International Conference on Alkali Reactivity;
- Member, Sub-Committee on Aggregate/Concrete Testing & Standards, Canadian Standards Association;
- Chairman, Program Committee, International Workshop on Alk-Aggregate Reactions in Concrete and Construction and Rehabilitation of Concrete Parking Structures.

Townsend, M.G.
- Consultant to International Group of Experts on Methodology and Monitoring of Radon, Thoron and their Daughters, Nuclear Energy Agency, Organization for Economic Cooperation and Development.

Wilson, H.S.
- Secretary Treasurer, 2nd International Conference on the Use of Fly Ash, Slag, and Silica Fume, Madrid, 1986.

CANADA

Federal

Bedard, P.
- Member, MSL-EDP Committee.

Bell, K.E., Andrews, P.R.A., Wilson, H.S., Lamothe, J.-M., Soles, J.A., Doyle, D., Wang, S.D.
- Members, Interbranch Liaison, Industrial Mineral (ILIM).

Bell, K.E.
- Member, (CANMET/MSL) Interdepartmental Working Group on Advanced Industrial Materials.

Bowman, W.S.
- Member, Data Management Users' Group, EMR Computer Science Centre.

Campbell, M.C.
- Chairman, BIOMINET;
- Chairman, MSL-EDP Committee;
- Member, CANMET EDP Acquisitions Committee;
- Member, Uranium Resource Appraisal Group;
- Member, Interdepartmental Working Group on Biotechnology.

Collings, R.K.
- Chairman, Interbranch Liaison, Industrial Mineral (ILIM).

Hitchen, A., Horton, R.E., Lalonde, C.
- Members, EMR Committee on Occupational Health and Safety.

John, R.D.
- Member, Advisory Committee, Second International Conference on Radioactive Waste Management.

Parsons, H.W.
- Secretary, BIOMINET

Pilgrim, R.F.
- Member, MSL-EDP Committee.

Quon, D.H.H.
- Member, Industry/CANMET Task Force on Iron Ore.

Riley, G.W.
- Member, Federal/Provincial Intergovernmental Working Group on Asbestos;
- Chairman, Federal/Provincial Sub-Group on Asbestos Fibre Measurement;
- Co-ordinator, CAN/EC Cooperative Research Program on Asbestos Fibre Measurement.

Sabourin, R.G.
- Member, Interdepartmental Committee on Standards Policy.

Smith, C.W.
- Member, MSL-EDP Advisory Committee.

Stefanski, M.
- Co-chairman, Technical Sub-committee for Mining and Mineral Technology, CANADA/NEWFOUNDLAND Mineral Development.

Sutarno, R.
- Member, MSL-EDP Committee;
- Member, CANMET EDP Acquisitions Committee.

Townsend, M.G.
- Member, Natural Sciences and Engineering Research Council, Committee on Technology for Silicon Integrated Circuits.

Department of Regional Industrial Expansion

Craigen, W.J.S.
- Member, Technical Advisory Committee for the Canada - New Brunswick Sulphation Roast-Leach Pilot Plant.

Inter-Governmental Maritime Consultative Organization

Steger, H.F.
- Member, Bulk, Cargoes Committee.

Canadian General Standards Board

Bell, K.E.
- Chairman, Committee GP-10, Refractories;
- Member, Committee GP-75, Ceramic Tile.

Douglas, E, Nebasar, B.
- Members, Committee GP-34, Asbestos-Cement Products.

University of British Columbia

The Centre for Metallurgical Process Development

Campbell, M.C.
- Member, Technical Advisory Board.

Riley, G.W.
- Member, Committee GP-8, Sieves, Testing, Woven Wire;
- Member, Committee GP-34, Asbestos-Cement Products.

Wang, S.S.
- Member, Committee GP-51, Thermal Insulation.

Environment Canada

Joe, E.G.
- Member, Gold Processors Working Group.

National Research Council of Canada

Riley, G.W.
- Member, Committee on Industrial Research Assistance.

Miscellaneous

Canadian Ceramic Society

Ahmad, A.
- Chairman, Electronics and Basic Science Division.

Bell, K.E.
- Editor-in-Chief of the Journal.

Wheat, T.A.
- Director, Electronics Basic Science Division;
- Vice-Chairman, Ceramographic Competition;
- Chairman, Publications Committee.

Canadian Institute of Mining and Metallurgy

Cabri, L.J.
- Representative, Special Volumes.

Doyle, D.
- Secretary, Canadian Mineral Processors Division;
- Member, Membership Committee.

Dutrizac, J.E.
- Co-chairman, 1986 International Symposium on Iron Control in Hydrometallurgy;
- Member, Historical Metallurgical Committee;
- Member, Hydrometallurgy Section Executive.

Laguitton, D.
- Member, Computer Applications and Process Control Committee.

Lalonde, C.
- Building Representative, 555 Booth St.

MacKinnon, D.J.
- Publicity Chairman, 1986 International Symposium on Iron Control in Hydrometallurgy.

Petruk, W.
- Chairman, Geology Division.

Mainwaring, P.R.
- Chairman, Mineral Sciences and Metallography Section, Metallurgical Society.

Ritcey, G.M.
- Member, Hydrometallurgy Section Executive.

Canadian Mineral Processors Conference

Joe, E.G.
- Treasurer.

Doyle, D.
- Secretary.

Canadian National Committee for the International Union of Crystallography

Szymanski, J.T.
- Secretary.

Canadian Standards Association

Carette, G.G.
- Member, Committee on Cement (A.5);
- Member, Committee on Cement Admixtures.

Andrews, R.P.A.
- Member, Committee on Gypsum and Lime (A.82);
- Chairman, Editorial Sub-Committee.

Malhotra, V.M.
- Member, Executive Committee on Aggregates and Concrete (A.23.1, A.23.2, A.24.3);
- Member, CSA Committee (A.23.1).

Soles, J.A.
- Member, Sub-Committee on Cement-Aggregate Reactivity;
- Member, Committee on Cement and Aggregate.

Sutarno, R.
- Member, Committee on Applications of Statistical Methods.

Canadian Society of Civil Engineering

Malhotra, V.M.
- Member, Technical Activities Committee;
- Associate Editor, Canadian Journal of Civil Engineering.

Canadian Uranium Producers's Metallurgical Committee

Dalton, J.L.
- Treasurer, Analytical Sub-Committee.

Ritcey, G.M.
- Secretary, Metallurgical Committee.

Chemical Institute of Canada

Hole, J.C.
- Chairman, Committee of Scrutineers.

Leaver, M.E.
- Treasurer, Ottawa Section Executive.

Iron Ores Processors Task Force

Cameron, W.
- Chairman and Secretary.

Mineralogical Association of Canada

Cabri, L.J.
- President;
- Associate Editor, Canadian Mineralogist;
- Representative to Canadian Geoscience Council.

Szymanski, J.T.
- Associate Editor, Canadian Mineralogist.

Spectroscopy Society of Canada

Leaver, M.E.
- Vice-chairperson, Ottawa Valley Section.

Whittwer, J.W.
- Director, Ottawa Valley Section.

UNITED STATES OF AMERICA

American Concrete Institute

Malhotra, V.M.
- Member, Technical Activities Committee;
- Member, ACI Committee 114 on Research Needs in Concrete;
- Chairman, ACI Committee 226/Sub-Committee on Silica Fume;
- Member, Malesian Research Council;
- Member, Publication Committee;
- Member, Convention Committee;
- Member, Technical Committee (214, 226, 228 and 568).

American Institute of Mining, Metallurgical and Petroleum Engineers

Dutrizac, J.E.
- Member, Publications Committee;
- Member, Lead, Zinc, Tin Committee.

Mainwaring, P.R.
- Member, Process Mineralogy.

Petruk, W.
- Chairman, Methodology, Process Mineralogy.

American Society for Testing and Materials

Horton, R.E.
- Member, Committee E.02, Emission Spectroscopy;
- Leader, Task Group on Line Overlap in X-ray Spectrometry.

Malhotra, V.M.
- Member, Committee C.09, Concrete;
- Chairman, C.09.02.05, Sub-Committee on Non-Destructive Testing of Concrete.

Sutarno, R.
- Member, Executive Committee of E-16, Sampling and Analysis of Metal-Bearing Ores;
- Member, Working Group on Sampling.

National Research Council, U.S.A. - Transportation Research Board

Malhotra, V.M.
- Chairman, Committee A2 E.03, Mechanical Properties of Concrete.

PART D. PUBLICATIONS, PAPERS, PRESENTATIONS AND REPORTS

Books

Townsend, M.G. "Metrology and Monitoring of Radon, Thoron and Their Daughter Products"; Nuclear Energy Agency, OECD; 1985.

Articles and Chapters Published in Books

Chen, T.T. and Haque, K.E. "Mineralogical Examination of Leach Residues of Uranium Ore from Midwest Lake, Northern Saskatchewan, Canada"; In: Process Mineralogy ICAM'84; 1984.

Collings, R.K. "Mineral Wastes"; In: The Geology of Industrial Minerals in Canada; Special Volume 29, The Canadian Institute of Mining and Metallurgy; 1985.

Ritcey, G.M. "Solvent Extraction in Uranium Ore Processing"; In: Solvent Extraction and Ion Exchange in the Nuclear Fuel Cycle, Ed. D.H. Logsdail and A.L. Mills; 1985.

Papers Published in Conference Proceedings

Ahmed, S.M. and Leduc, J. "Photoelectrochemical Behaviour of n-GaAs with Cobalt Films"; Extended Abstracts, Electrochemical Society 85-2:515-516; 1985.

Cabri, L.J. and Laflamme, J.H.G. "Mineralogy and Metallurgical Balance of Platinum-Group Elements in Mill Products From Sudbury"; Proceedings of ICAM'84, Los Angeles, AIME 911-922; 1985.

Dutrizac, J.E. "Recent Advances in the Leaching of Sulphides and in the Precipitation of Iron"; Proceedings of MINTEK 50, 39-62; 1985.

Dutrizac, J.E. "Silver Behaviour in Hydrometallurgical Zinc Circuits"; Proceedings of International Symposium on Extractive Metallurgy of Zinc 707-727; 1985.

Dutrizac, J.E. and Jambor, J.L. "Formation and Characterization of Argento-jarosite and Plumbojarosite and Their Relevance to Metallurgical Processing"; Applied Mineralogy, 2nd International Congress, Los Angeles, Trans AIME, 507-530; 1983.

Dutrizac, J.E. and Jambor, J.L. "Impurity Control During Jarosite Precipitation"; Proceedings of the 15th Annual Meeting of the Hydrometallurgy Society, Vancouver, CIM Paper 23; 1985.

Hamer, C.A. "Evaluation of SO_2 Sorbent Utilization in Fluidized Beds"; Proceedings of the International Conference on Fluidized Combustions; 1984.

Laguitton D. "A First Generation of Software for the Canadian Mineral Processors SPOC Project - Annual Report 1984-1985"; 17th Annual Proceedings of the Canadian Mineral Processors; 1985.

Laguitton, D. and Flament, F. "On-Line Software Demonstrations for Mineral and Coal Processors"; Proceedings of the CMP; 1984.

Laguitton, D., Pilgrim, R.F. and Sequin, F.X. "Steady State Simulation of Comminution Circuits"; Proceedings of the Computer Simulation Conference, Vancouver; 1983.

Malhotra, V.M., Carette, G.G. and Aitcin, P.C. "Mechanical Properties of Portland Cement Concrete Incorporating Blast-Furnace Slag and Condensed Silica Fume"; Proceedings of the ACI/RILEM Symposium, Monterrey, Mexico; 395-414; 1985.

Mathieu, G.I. and Sirois, L.L. "New Processes to Float Feldspathic and Ferrous Minerals From Quartz"; Proceedings of '84 Institution of Mining and Metallurgy Conference, Rome, Italy; 1984.

Mikhail, S.A. "Characterization of Reaction Products in a Fluid Bed Coal Combustion Process by Thermal Analysis"; Supplement to the Proceedings of the 8th International Conference on Thermal Analysis, Bratislava, Czechoslovakia; 116-123; 1985.

Petruk, W. "Applied Mineralogy in Ore Dressing of Volcanogenic Massive Sulfide Ores"; AIME Special Volume ICAM'84, Part 2 279-290; 1983.

Petruk, W. "Image Analysis Measurements and Data Presentation for Mineral Dressing Applications"; AIME Special Volume ICAM'84, Los Angeles; 127-140; 1984.

Pouskouleli, G. and Demopoulos, G.P. "Direct Recovery of Precious Metals by Integration of Solvent Extraction and Hydrogen Reduction Techniques"; Proceedings of the IPMI Conference; 1984.

Ritcey, G.M., Gee, G.W. and Kalin, M. "Report of the Working Groups of CRP - Radium 2 - Rio de Janeiro, February 1984"; Proceedings of IAEA; 1984.

Rolia, E. and Tan, K.G. "Chemical Oxidation of Thiosalt-Containing Milling Effluents"; Proceedings of the 15th Annual Meeting of the Hydrometallurgical Meeting 27:1-23; 1986.

Papers Published in Outside Journals

Ahmed, S.M. Book Review: "'MODERN ASPECTS OF ELECTROCHEMISTRY' Volume 14, Edited by J.O'M Bockris (Texas A&M Univ.), B.E. Conway (Univ. of Ottawa) and R.E. White (Texas A&M Univ.). Plenum Press, New York (N.Y.), London, 1982, xvi 661 pp. $55"; J. Colloids and Surfaces 11:437-438; 1984.

Ballet, O., Coey, J.M.D., Mangin, P. and Townsend, M.G. "Ferrous Talc - A Planar Antiferromagnet"; Solid State Communication 55: 787-790; 1985.

Cabri, L.J., Campbell, J.L., Leigh, R.G., Maxwell, J.A., and Scott, J.D. "Proton Microprobe Analysis of Trace Elements in Sulfides From Some Massive Sulfide Deposits"; Can Mineral 23:133-148; 1985.

Campbell, M.C., Parsons, H.W., Jongejan, A., Sanmugasunderam, V. and Silver, M. "Biotechnology for the Mineral Industry"; Can Metall 24:2: 115-120; 1985.

Campbell, M.C., Ritcey, G.M. and Gow, W.A. "Canada's Uranium Industry - The Next Decade"; CIM Bull 78:875:139-144; 1985.

Craigen, W.J.S. and Wittur, G.E. "Factors Affecting the Viability of Canada's Copper Producers"; CIM Bull 79:885:81-88; 1986.

Carrette, G.G. and Malhotra, V.M. "Performance of Dolostone and Limestone Concretes at Sustained High Temperatures"; ASTM STP 858:38-67; 1985.

Dinardo, O. and Dutrizac, J.E. "The Solubility of Silver Chloride in Ferric Chloride Leaching Media"; Hydrometallurgy 13:345-363; 1985.

Donaldson, E.M. and Wang, M. "Methyl Isobutyl Ketone Extraction of Iodide Complexes From Sulphuric Acid - Potassium Iodide Media and Back-Extraction into an Aqueous Phase"; Talanta 33:35-44; 1986.

Dutrizac, J.E. "The Dissolution of Galena in Ferric Chloride Media"; Metall Trans 17B:5-17; 1986.

Dutrizac, J.E, Chen, T.T. and Jambor, J.L. "Mineralogical Changes Occurring During the Ferric Ion Leaching of Bornite"; Metall Trans 16B:679-693; 1985.

Dutrizac, J.E. and O'Reilly, J.B. "The First Cyanide Leaching Plants in Canada"; CIM Bull 78:876:75-76; 1985.

Dutrizac, J.E. and O'Reilly, J.B. "Further Observations on Canada's First Cyanide Leaching Plant"; CIM Bull 78:880:70-71; 1985.

Jambor, J.L. and Dutrizac, J.E. "Synthesis of Beaverite"; Can Mineral 23:47-51; 1985.

MacKinnon, D.J. The Effect of Copper on Zinc Electrowinning From Industrial Acid Sulphate Electrolyte"; J. Appl Electrochem 15:953-960; 1985.

MacKinnon, D.J., Brannen, J.M. and McMillan, R.S. "Factors Affecting the Structure of Copper Deposits Electrowon From Aqueous Chloride Electrolyte"; J. Appl Electrochem 15:649-658; 1985.

MacKinnon, D.J. and Brannen, J.M. "Aluminum Cathode Effects in Zinc Electrowinning From Industrial Acid Sulphate Electrolyte"; J Appl Electrochem 16:127-133; 1986.

MacKinnon, D.J., Morrison, R.M. and Brannen, J.M. "The Effects of Nickel and Cobalt and Their Interaction with Antimony on Zinc Electrowinning From Industrial Acid Sulphate Electrolyte"; J Appl Electrochem 16:53-61; 1986.

Malhotra, V.M. "Superplasticizers in Concrete"; Civil Engineering 57-59; December 1984.

Malhotra, V.M. and Carrette, G.G. "Performance of Concrete Incorporating Limestone Dust as Partial Replacement for Sand"; ACI J 363-371; May-June 1985.

McCorkell, R.H., Smith, C.W. and Dalton, J.L. "Beta-Counting Methods for Measurement of Lead-210 and Their Application to CCRMP Reference Materials"; Can J. Spectroscopy 30:30-36; 1985.

Mikhail, S.A. "A Modification to Dupont 951 TGA - 1090 Thermal Analysis System for Concurrent Thermogravimetry and Differential Thermal Analysis"; Thermochemica Acta 95:287-290; 1985.

Mirkovich, V.V. and Wheat, T.A. "Thermal Transport Properties of CaO-Stabilized Zirconia with Varying Amounts of Stabilization"; High Temperatures - High Pressures 17:5:67-73; 1985.

Quon, D.H.H., Wang, S.S.B. and Chen, T.T. "Viscosity Measurements of Slag From Western Canadian Coals"; J Eng Gas Turbines and Power 107:803-806; 1985.

Ritcey, G.M. and Wong, E.W. "Influence of Cations on Crud Formation in Uranium Circuits"; Hydrometallurgy 15:55-61; 1985.

Silver, M. and Ritcey, G.M. "Effects of Iron-Oxidizing Bacteria and Vegetation on Acid Generation in Laboratory Lysimeter Tests on Pyrite-Containing Uranium Tailings"; Hydrometallurgy 15: 255-264; 1985.

Silver, M., Ritcey, G.M. and Cauley, M.P. "A Lysimeter Comparison of the Effects of Uranium Tailings Deposition Methods on the Release of Environmental Contaminants"; Hydrometallurgy 15: 159-172; 1985.

Steger, H.F. "Effect of EDTA/NaF Solutions on the Orion Cu(II) Ion-Selective Electrode"; Talanta 32:235-237; 1985.

Steger, H.F., Bowman, W.S. and McKeague, J.A. "Additional Certified Values for CCRMP Soils SO-1 to -4"; Geostandards Newsletter 9:213-218; 1985.

Steger, H.F. and Smith, C.W. "Recommended Lead-210 Values for Four CCRMP Uranium Reference Materials"; Geostandards Newsletter 9:229-231; 1985.

Steger, H.F. and Sutarno, R. "Estimation of the Variance of Values from Calibration Curves"; Document ISO/REMCO 118; April 1985.

Sutarno, R. "Procedure for Statistical Evaluation of Analytical Data Resulting From International Tests"; Document ISO/TC 102 Technical Committee Report; 1985.

Sutarno, H.F. and Bowman, W.S. "ISO/TC 69/SC 6/WG 1 - Precision of Test Methods - Determination of Repeatability and Reproducibility by Interlaboratory Tests - Comparison of Alternative Test Methods"; Document ISO Standard 5725; 1985.

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Ahmad, A.
"Traditional and Advanced Ceramics (Poster Session)"; Queen's University, Kingston, Ontario; July 1985.

Ahmed, S.M.
"Canadian Contribution to the IEA, Task VI, Program of Research and Development for Photocatalytic Electrolysis of Water to Produce Hydrogen Using Solar Energy"; IEA Workshop, University of Leuven, Belgium; April 1985.

Barkley, D.J.
"High-performance Ion-exchangers for the Determination of Rare-earths"; CANMET, MSL Seminar, Ottawa, Ontario; June 1985.

"Dynamic Ion-exchange Chromatographic Separation of Rare-earths and Thorium in Samples From Processing of Uranium Ores"; Rocky Mountain Conference, Denver, Colorado; July 1985.

Cabri, L.J.
"PIXIE Analysis of Mineralogical Specimens"; Spectroscopy Society of Canada Annual Conference, Toronto, Ontario; 1985.

"Mineralogical Applications of Particle Induced X-ray Analysis (PIXIE)"; Workshop on Trace Element Geochemistry With Particle and Proton Beams, Brookhaven National Laboratory, Upton, N.Y.; June 1985.

"Trace Elements in Sulfide Minerals by Milliprobe X-ray Fluoresence Using White Synchrotron Radiation"; American Geophysical Union, San Francisco, California; December 1985.

Craigen, W.J.S.
"Economics of Chemical Methods for Copper Extraction and Refining"; 69th Canadian Chemical Conference, Kingston, Ontario; June 1985.

"Economic Incentives for the Production of Bulk Base Metal Sulfide Concentrates"; International Symposium on Complex Sulfides, San Diego, California; November 1985.

Canaday, J.D.
"A Micro-computer System for Fuel Cell Experiments"; Annual Meeting of the Electrochemical Society, Toronto, Ontario; May 1985.

Chen, T.T.
"Constituents in Lime Products Used in the Paper Industry"; Geological Society of Canada and Mineralogical Society of Canada Joint Annual Meeting, Fredericton, N.B.; May 1985.

"Results of Mineralogical Studies on Copper Anode Slimes"; 2nd Meeting of the CANMET-Industry-University Working Group on Impurities in Copper Refining, INCO Ltd., Copper Cliff, Ontario; June 1985.

"The Mineral Forms of Silver in Zinc Leaching Residues"; 24th Annual Conference of Metallurgists, Vancouver, B.C.; August 1985.

Cristovici, M.A.
"Recovery of Gold From Old Tailing Ponds"; CIM-AGM, Vancouver, B.C.; August 1985.

Dalton, J.L.

"Natural Isotope Activity Measurements by Gamma-ray Spectrometry"; Analytical Subcommittee/Canadian Uranium Producers Metallurgical Committee, Saskatoon, Saskatchewan; May 1985.

"An Overview of the Preparation of Biological Reference Materials From the Cluff Lake Mining Area and the Gamma-ray Methodology at CANMET"; Workshop on Analytical Chemistry Related to Canada's Nuclear Industry, Kimberley, Ontario; October 1985.

Douglas, E.

"Characterization of Algoma Blast-Furnace Slag"; Presentation at Seminar "Blast-Furnace Slag Cements for Use in the Mining Industry"; Sudbury, Ontario; September 1985.

Dutrizac, J.E.

"Impurity Control During Jarosite Precipitation"; 15th Annual Hydrometallurgical Meeting, Vancouver, B.C.; August 1985.

"Silver Behaviour in Hydrometallurgical Zinc Circuits"; International Symposium on the Extractive Metallurgy of Zinc"; Tokyo, Japan, October 1985.

"Silver Control in Zinc Processing"; Seminar at Kyoto University, Kyoto, Japan; October 1985.

Harrison, W.

"Safety Assessment of Uranium Mill Tailings Program"; Canadian Nuclear Society Conference, Ottawa, Ontario; June 1985.

John, R.D.

"The National Uranium Tailings Program"; Chemical Institute of Canada Conference, Kingston, Ontario; June 1985.

"The NUTP - Current Status"; IAEA CRP on Environmental Migration of Radon and Other Contaminants Present in Liquid and Solid Wastes from the Mining and Milling of Uranium, Third Research Coordination Meeting, Cadarache, France; September 1985.

Laguitton, D.

"SPOC Software"; Workshops Organized by Canadian Industrial Computer Society, CMI-METSOC, Vancouver, B.C.; August 1985.

Leduc, J.

"Photoelectrochemical Behaviour of n-GaAs with Cobalt Films"; Electrochemical Society Meeting, Las Vegas, Nevada; October 1985.

Mainwaring, P.R.

"Automatic Electron Microprobe Image Analysis"; 16th Annual Meeting of Fine Particle Society, Miami Beach, Florida; April 1985.

"Applied Mineralogy of Refractory Gold Ores"; Special Session on Applied Mineralogy; and

"Automatic Image Analysis Applied to Mineral Processing Problems"; Mineralogical Association of Canada, Annual Meeting, Fredericton, N.B.; May 1985.

"Mineralogy of Gold in Feeds and Process Products"; 24th Conference of Metallurgists, Vancouver, B.C.; August 1985.

Malhotra, V.M.

"Mechanical Properties of Portland Cement Concrete Incorporating Blast-Furnace Slag and Condensed Silica Fume"; Invited Presentation at the ACI/RILEM Symposium on "Technology of Concrete when Pozzolans, Slags and Chemical Admixtures are Used"; Monterrey, Mexico; March 1985.

Invited by the Norwegian Concrete Institute and SCANCEM A/C Norway to present a state-of-the-art paper on Concrete Technology at the meetings of the Institute and at SCANCEM A/C; May 1985.

Opening remarks at the CANMET sponsored two-day International Workshop on Alkali-Aggregate Reactions in Concrete and Deterioration of Parking Structures, Montreal, Quebec; May 1985.

Invited by CSNDT, Toronto to conduct a U.N. sponsored 5-day course on NDT of Concrete at Buenos Aires, Argentina; November 1985.

Invited by the University of Wisconsin - Extension Department to participate in a program "Concrete Testing by NDT Methods"; Milwaukee; November 1985.

Addressed a dinner meeting of the ACI Chapter, Dallas, Texas; November 1985.

"Development in Materials Technology: A State-of-the-Art"; and

"Non-Destructive Testing of Concrete Strength"; Invited presentations at an International Colloquim on "Concrete in Developing Countries"; Lahore, Pakistan; December 1985.

Mathieu, G.I.

"Dry Cleaning of Coal - Existing and New Technology"; CIM-AGM, Vancouver, B.C.; April 1985.

"Progressive Grinding and Processing of Coal"; Engineering Foundation Conference - Science and Technology of Processing Fine Coal, Henniker, N.H.; August 1985.

Mikhail, S.A.
"Characterization of Reaction Products in a Fluid Bed Coal Combustion Process by Thermal Analysis"; 8th International Conference on Thermal Analysis, Bratislava, Czechoslovakia; August 1985.

Moon, K.S.
"Method for Analysing Different Sulphur Forms in Coal"; First International Conference on Processing and Utilization of High Sulphur Coals, Columbus, Ohio; October 1985.

Pilgrim, R.F.
"SPOC Project Software and Manual"; 18th Canadian Mineral Processors Operators Conference, Ottawa, Ontario; January 1986.

"SPOC Project Update"; Canadian Mineral Processors 18th Annual Meeting, Ottawa, Ontario; January 1986.

Ritcey, G.M.
"Treatment of Gold Mill Tailings"; McGill University Seminar on Mineral Processing of Gold Ores; May 1985.

Seminar on Treatment of Gold Mill Tailings, United Keno Hill Mines, Yukon; June 1985.

"Silica Fouling in Ion Exchange, Carbon in Pulp and Solvent Extraction"; CIM Hydrometallurgy Meeting, Vancouver, August 1985.

"Solvent Extraction in Uranium Ore Processing"; Meeting on Solvent Extraction and Ion Exchange in the Nuclear Fuel Cycle, Harwell, U.K.; September 1985.

"Simulated Tailings Weathering Tests in Lysimeters"; IAEA Meeting on Tailings, Cadarache, France; September 1985.

"Non-Nuclear Metallurgical Applications of TBP"; Two 1-hour seminars presented as invited Plenary papers at meeting of Japanese Association of Solvent Extraction, Tokyo, Japan; December 1985.

"Rare Earths in China"; Seminar to Nippon Mining Research, Tokyo, Japan; December 1985.

"Solvent Losses and the Environment"; and

"Silica Fouling in Hydrometallurgy"; Seminar at Tohoku University, Sendai, Japan; December 1985.

"Solvent Extraction and Hydrometallurgy Research for the Future"; Seminar at Shizuoka University, Hamamatsu, Japan; December 1985.

"Non-Nuclear Metallurgical Applications of TBP"; Seminar at Kansai University, Osaka, Japan, December 1985.

Skeaff, J.M.
"Thermochemical Arsenide-Oxide Equilibria in the System Ni-As-O"; 1985 AIME-CIM Extractive and Process Metallurgy Meeting, San Diego, California; October 1985.

Soles J.A.
"The Influence of Mineral Admixtures on Alkali-Aggregate Reactivity"; International Workshop on Alkali-Aggregate Reactions in Concrete and Construction and Rehabilitation of Concrete Parking Structures, Montreal, Quebec; May 1985.

Steger, H.F.
"CCRMP and International Status of Reference Materials"; Centre de Recherches Minérales, Québec City, Quebec; March 1985.

"Update of the Measurements Program of NUTP"; Workshop on Analytical Chemistry Related to Canada's Nuclear Industry, Kimberley, Ontario; October 1985.

Tan, K.G.
"Chemical Oxidation of Thiosalt-Containing Milling Effluents" 15th Annual Hydrometallurgy Meeting, CIM, Vancouver, B.C.; August 1985.

"Chemical Oxidation of Thiosalt-Containing Milling Effluents"; CANMET, MSL Seminar, Ottawa, Ontario; November 1985.

Tan, L.K.
"Determination of Arsenic(III) and Arsenic(V) in Acidic Ferric Chloride or Ferric Sulphate Leaching Media by Ion Chromotography"; 27th Rocky Mountain Conference, Denver, Colorado; July 1985.

Tremblay, G.
"The NUTP - An Interim Report"; Seminar on Engineering of Waste Management Systems, University of Saskatchewan, Saskatoon, Saskatchewan; August 1985.

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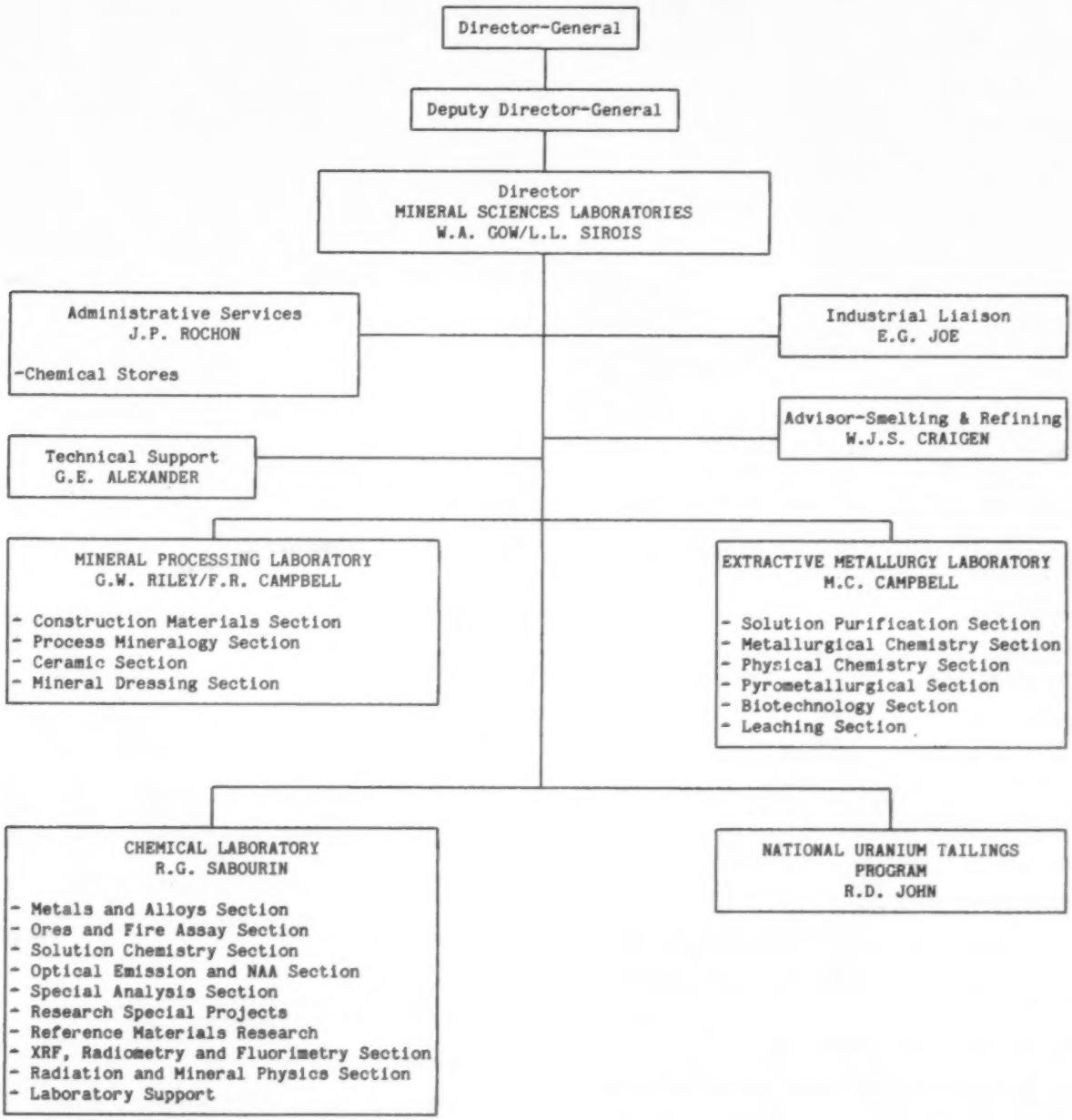
PART E. ORGANIZATION AND PROFESSIONAL STAFF

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY (CANMET)

MINERAL SCIENCES LABORATORIES



MINERAL SCIENCES LABORATORIES

W.A. Gow; B.A.Sc. (Toronto); Director
L.L. Sirois; B.A., B.Eng., M. Eng. (McGill); P. Eng.; Director
E.G. Joe; B.Sc. (Queen's); Phys. Sci.
W.J.S. Craigen; B.Sc. (Queen's); Phys. Sci.

CHEMICAL LABORATORY

R.G. Sabourin; B.Sc. (Ottawa); Manager
R.J. Guest; B.Sc. (Acadia); Asst. Manager Operations

METALS AND ALLOYS

D.J. Barkley; B.Sc. (Carleton); Chemist
E.H. MacEachern; B.Sc. (Mount Allison); Chemist
J.W. Wittwer; B.Sc. (Carleton); Chemist

ORES AND FIRE ASSAY

J.C. Hole; B.A. (Toronto); Chemist
R.R. Craig; B.Sc. (Glasgow); Chemist

SOLUTION AND CHEMISTRY

G.A. Hunt; B.Sc. (Carleton); Chemist
J.E. Atkinson; B.A. (Queen's) Chemist
J.A. Graham; B.Sc. (Carleton); Chemist

OPTICAL EMISSION AND NAA

T.R. Churchill; B.Sc. (Western Ontario); Chemist
R.E. Horton; B.Sc. (Carleton); Chemist

SPECIAL ANALYSIS

A. Hitchen; B.Sc. (McMaster); Chemist
M.E. Leaver; B.Sc. (Queen's); Chemist

RESEARCH/SPECIAL PROJECTS

E.M. Donaldson; B.Sc. (Manitoba); Res. Sci.
E. Mark; B.A. (Toronto); Chemist

REFERENCE MATERIALS RESEARCH

H.F. Steger; B.Sc., Ph.D. (McMaster); Res. Sci.

RADIATION AND MINERAL PHYSICS

M.G. Townsend; B.Sc., Ph.D. (Southampton); Res. Sci.
R. Provencher; B.Sc., M.Sc., Ph.D. (Sherbrooke); Res. Sci.

XRF, RADIOMETRY AND FLUORIMETRY

J.L. Dalton; B.Sc. (Manitoba); M.Eng. (Carleton); Chemist
R.H. McCorkell; M.Sc., Ph.D. (Manitoba); Chemist
D.L. Curley; B.Sc. (Carleton); Chemist
M. Desgagne; B.Sc. (Laval); Chemist
C.W. Smith; M.Sc., Ph.D. (Queen's); Res. Sci.

EXTRACTIVE METALLURGY LABORATORY

M.C. Campbell; B.Sc. (St. Francis Xavier), B.Eng. (N.S.T.C.), D.I.C., M.Sc. (London); P.Eng.; Manager
D.H. Bell; B.A.Sc. (Toronto); Ph.D. (London); DIC (Imperial Coll.); Phys. Sci.

SOLUTION PURIFICATION

G.M. Ritcey; B.Sc. (Dalhousie); Res. Sci.
R. Molnar; B.Eng. (McGill); Ph.D. (Univ. of London); DIC; Res. Sci.
G. Pouskouleli; B.Sc. (Aristotelian Univ., Greece); M.Sc. (Université de Montréal); Ph.D. (McGill Univ.); Res. Sci.
G. Deschênes; B.Sc., M.Sc. (Laval); Phys. Sci.

METALLURGICAL CHEMISTRY

J.E. Dutrizac; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
D.J. MacKinnon; B.Sc., M.A., Ph.D. (Ottawa); Res. Sci.
R.M. Morrison; B.Sc., Ph.D. (UBC); Res. Sci.
O. Dinardo; B.Sc. (Carleton); Phys. Sci.
K. Bartels; B.Sc. (Carleton); Chemist
E. Rolia; B.A. (UBC); Chemist
K.G. Tan; M.Sc.Chem. (Univ. of Aachem, Germany); Ph.D. (Carleton); Res. Sci.

PHYSICAL CHEMISTRY

A.H. Webster; B.A., M.A., Ph.d. (UBC); Res. Sci.
S.M. Ahmed; B.Sc., M.Sc., Ph.D. (Saskatchewan); Res. Sci.
R.F. Pilgrim; B.Sc. (Queen's); Res. Sci.
R. Sutarno; B.E., M.E., Ph.D. (N.S.T.C.); P.Eng.; Res. Sci.
S.A. Mikhail; B.Sc., M.Sc., Ph.D. (Cairo); Dr.Eng. (Norway); Res. Sci.
J. Leduc; B.Sc. (Université de Montréal); M.Sc., Ph.D. (McGill); Res. Sci.
V.H.E. Rolko; B.Sc. (Manitoba); Chemist

PYROMETALLURGY

J.M. Skeaff; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
C. Hamer; B.E. (N.S.T.C.), M.Sc. (Queen's); P.Eng.; Res. Sci.
V.M. McNamara; B.Sc., B.Eng., M.A.Sc. (Toronto); P.Eng.; Res. Sci.
L.J. Wilson; B.Sc. (McMaster); Phys. Sci.
D. Liang; B.Sc., M.Sc. (Queen's); P.Eng.

BIOTECHNOLOGY

R.G.L. McCready; B.Sc., M.Sc. (Alberta); Ph.D. (Calgary); Res. Sci.
H.W. Parsons; B.Sc. (Alberta); Res. Sci.
A. Jongejan; Geol. Can. Drs., Ph.D. (Amsterdam); Res. Sci.

M. Silver; B.Sc., M.Sc. (Manitoba); Ph.D. (Syracuse); Res. Sci.
V. Sanmugasunderam; B.Sc. (Univ. of Ceylon); M.Sc. (Univ. of Wales); Ph.D. (UBC); Res. Sci.
W.D. Gould; B.Sc. (Manitoba); M.Sc., Ph.D. (Alberta); Res. Sci.

LEACHING

B.H. Lucas; B.Sc. (Queen's); P.Eng.; Res. Sci.
K.E. Haque; M.Sc., Ph.D. (Ottawa); Res. Sci.
D. Shimano; B.Sc. (Concordia); Phys. Sci.
W. Howell; B.Sc. (Calgary); M.Sc. (Ottawa); Phys. Sci.

MINERAL PROCESSING LABORATORY

G.W. Riley; A.C.S.M. (Camborne School of Mines); P.Eng.; Manager
F.R. Campbell; Eng.D. (St. Francis Xavier); B.Eng. (N.S.T.C.); Ph.D. (London); DIC (Imperial College); Manager
M. Stefanski; B.Sc., M.Sc., Ph.D. (Katowce); Ph.D. Krakow); Phys. Sci.

CONSTRUCTION MATERIALS

V.M. Malhotra; B.Sc., B.E. (W. Australia); Res. Sci.
H.S. Wilson; B.E. (Saskatchewan); Res. Sci.
B. Nebesar; M.Sc. (McGill); Res. Sci.
E. Douglas; B.Sc. (Chem. Eng.) (Argentina); Ph.D. (McGill); Res. Sci.
G.G. Carette; B.Sc. (Laval); Eng.

MINERAL DRESSING

D.M. Doyle; B.Sc. Min. Eng. (Michigan Technical Univ.); Phys. Sci.

Metallic

G.I. Mathieu; B.A., B.Sc. (Laval); Res. Sci.
A.I. Stemerowicz; B.Sc. (Queen's); P.Eng.; Res. Sci.
D. Laguitton; Chem. Eng. (Rennes); D.Sc. (Laval); Res. Sci.
K.S. Moon; B.Sc., M.Eng. (Seoul National Univ.); M.A.Sc., M.Eng. (UBC); Ph.D. (California); Res. Sci.
M. Cristovici; B. Mining and Metallurgical Eng. (Bucharest); P.Eng.; Res. Sci.
J.H.C. Leung; B.Sc. (Taiwan); M.Sc. (Waterloo); Phys. Sci.
W.H. Cameron; B.Sc. (Queen's); Phys. Sci.
V.G. Reynolds; B.Sc. (Carleton); Phys. Sci.
J.M. Lamothe; B. Mining Eng. (Ecole Polytechnique Montreal); Res. Eng.
M. Bilodeau; B.Sc. (Laval); Phys. Sci.

Non-Metallic

R.K. Collings; B.Eng. (N.S.T.C.); P.Eng.; Res. Sci.
S.S.B. Wang; B.Sc. (Hong Kong Baptist); M.Sc. (California); Ph.D. (Toronto); Phys. Sci.
P.R.A. Andrews; B.Sc. (London); M.Eng.Sc. (Melbourne); Res. Sci.

PROCESS MINERALOGY

P.R. Mainwaring; B.Sc. (UWO); Ph.D. (Toronto); Res. Sci.
L.J. Cabri; B.Sc., M.Sc., Ph.D. (McGill); Res. Sci.
J.L. Jambor; B.A., M.Sc., Ph.D. (Carleton); Res. Sci.
W. Petruk; B.Eng., M.Sc., Ph.D. (McGill); Res. Sci.
T.T. Chen; B.Sc., M.Sc., Ph.D. (Cornell); Res. Sci.
J.A. Soles; B.A.Sc., M.A.Sc. (British Columbia); Ph.D. (McGill); P.Eng.; Res. Sci.
J.T. Szymanski; B.Sc., Ph.D. (London); Res. Sci.
M.R. Hughson; B.A. (Western Ontario); Phys. Sci.
J.M.D. Wilson; B.Sc., M.A.Sc. (Queen's) Phys. Sci.
K.M. Besso; B.Sc. (Montreal); Phys. Sci.

CERAMICS

K.E. Bell; B.E. (Saskatchewan); P.Eng.; Res. Sci.
V.V. Mirkovich; Ph.D. (Toronto); Res. Sci.
D.H.H. Quon; B.Sc. (National Sun Yat Sen U); M.Sc. (Ohio State); Ph.D. (Michigan); Res. Sci.
T.A. Wheat; Ph.D. (Leeds); Res. Sci.
A. Ahmad; B.Sc., M.Sc., Ph.D. (New Brunswick); Res. Sci.
A.K. Kuriakose; B.Sc., M.A., Ph.D. (Madras, India); Res. Sci.
J.D. Canaday; M.BA (Univ. of Arizona); B.Sc. (Univ. of Oklahoma); Ph.D. (Univ. of Guelph); M.Sc. (Univ. of Guelph); M.Sc. (Univ. of Calgary); Res. Sci.

NATIONAL URANIUM TAILINGS PROGRAM

R.D. John; B.Sc. (Loughborough); CIMA (London/Lambton); Manager
H.F. Steger; B.Sc., Ph.D. (McMaster); Res. Sci.
D.G. Feasby; B.Sc., M.Sc. (Queen's); Phys. Sci.
R. Holmes; B.Sc., M.Sc. (Windsor); Phys. Sci.
G. Tremblay; B.Sc. (Carleton); Phys. Sci.
C. Weatherell; B.Sc. (Waterloo); Phys. Sci.
W.C. Harrison; M.Sc. (Alberta); Phys. Sci.

PART F. DISTRIBUTION OF RESOURCES

MSL - FISCAL YEAR 1985-86

PROGRAM - MINERAL AND EARTH SCIENCES
ACTIVITY - "A-BASE"

SUB-ACTIVITY	MSL $000's
14. MINING	
- Personnel (PY)	127(3)
- Operating	19
- Capital	10
20. COAL MINING AND PREPARATION	
- Personnel (PY)	213(5)
- Operating	32
- Capital	240
30. MINERAL PROCESSING	
- Personnel (PY)	7,395(174)
- Operating	1,137
- Capital	346
50. FUELS TECHNOLOGY	
- Personnel (PY)	43(1)
- Operating	Nil
- Capital	20
70. METALS AND MATERIALS	
- Personnel (PY)	128(3)
- Operating	20
- Capital	10
ACTIVITY TOTAL	
- Personnel (PY)	7,906(186)
- Operating	1,208
- Capital	626
TOTAL	9,740

PROGRAM - MINERAL AND EARTH SCIENCES
ACTIVITY - ENERGY R&D

SUB-ACTIVITY	MSL $000's
14. MINING	
- Personnel (PY)	
- Operating	
- Capital	
20. COAL MINING AND PREPARATION	
- Personnel (PY)	
- Operating	
- Capital	
30. MINERAL PROCESSING	
- Personnel (PY)	239(5)
- Operating	188
- Capital	545
50. FUELS TECHNOLOGY	
- Personnel (PY)	48(1)
- Operating	20
- Capital	30
70. METALS AND MATERIALS	
- Personnel (PY)	
- Operating	
- Capital	
ACTIVITY TOTAL	
- Personnel (PY)	287(6)
- Operating	208
- Capital	575
TOTAL	1,070

NATIONAL URANIUM TAILINGS PROGRAM
ACTIVITY - "A-BASE"

SUB-ACTIVITY	
30. MINERAL PROCESSING	
- Personnel (PY)	298(7)
- Operating	2,403
- Capital	50
TOTAL	2,751